CASSELL'S

EDUCATIONAL

PR63591

Library

of the

University of Toronto

English books at London prices | A Weekly parcel from London

FOWLER

from the Palais Royal.

279, Rue St. Honoré, 279

(NEAR THE RUE ROYALE)

SCIENCE
POPULARLY EXPLAINED:

The Principles of Natural and Physical Science,

AND

THEIR PRACTICAL AND USEFUL APPLICATIONS TO THE EMPLOYMENTS AND NECESSITIES OF COMMON LIFE,

FAMILIARLY EXPLAINED.

ILLUSTRATED WITH UPWARDS OF TWO HUNDRED ENGRAVINGS.

BY

DAVID A. WELLS, A.M.

WITH ADDITIONS BY THE EDITORS.

LONDON:
CASSELL, PETTER, AND GALPIN,
LA BELLE SAUVAGE YARD,
LUDGATE HILL, E.C.

Digitized by the Internet Archive
in 2018 with funding from
University of Toronto

https://archive.org/details/sciencepopularly00well

PREFACE.

THE success which has attended the Educational Works already issued by the Editor, the circulation they have attained, and the popularity they have secured, have induced him to undertake the present Series. He is confident that such a Series is required; that self-education is one of the peculiar characteristics of the age; that the people are bent on obtaining information, and that those who render that information easy of access are doing good service. His object is to place within the reach of all an EDUCATIONAL LIBRARY; to render it at once accurate in matter, attractive in manner, and cheap in price.

This, the First Volume of the EDUCATIONAL COURSE, is devoted to "Science Popularly Explained." The system of instruction which constitutes its marked and peculiar features embraces the whole circle of the Natural and Physical Sciences, so far, at least, as their elementary principles and practical applications are concerned.

Notwithstanding so many and such extensive departments of scientific knowledge are included within the limits of a single volume, the Editor is confident that a careful examination of the separate divisions will show that the Principles of each Science are carefully and distinctly set forth, and that many of their practical applications to familiar objects are illustrated and explained.

The Editor is aware that with some persons strong objections exist against any system of instruction based on the plan of Question and Answer; and some deprecate all attempts to popularise scientific truth—considering that science is degraded by clothing its principles in garments drawn from a homely wardrobe. He would urge in reply, that the extensive circulation and continued use of such works in England, France, and the United States, show that it meets a want not adequately supplied, and that this plan of instruction is both popular and practical. His aim is to familiarise the mind with the great principles of the various branches of science treated, and at

the same time show how intimately they are connected with all the occupations of everyday life. And this communication of scientific truth he claims to be effected, so far especially as young persons are concerned, more perfectly by a well-arranged system of Question and Answer than in any other way; since a true system of instruction does not consist in presenting to the mind facts to be retained simply as such, but in making facts familiar, in pointing out their dependence on general laws, and illustrating their practical applications. The Question appeals directly to the curiosity of the learner; and this feeling, when aroused, concentrates the mind, and occasions a corresponding distinctness to all its perceptions. It appeals also to the reasoning faculties: to the mind, as an intelligent and investigating agent; and not to one single attribute—the memory. The knowledge which the pupil acquires in this way is fixed and permanent. It is continually recalled by the presence of the familiar objects treated of, which in their turn re-act, suggesting generalisations, and encouraging the deduction of other and more important inferences.

These remarks, however, apply only to the present volume. The plan of Question and Answer is not adopted in the volumes which immediately follow. With respect to these,—the "Treatise on the English Language," and also that on "Astronography,"—copious Questions are given at the end of each Chapter, which may be employed at discretion, the Editor being fully convinced of the utility of such a mode of examination.

London, September, 1856.

CONTENTS.

CHAPTER — PAGE

LAWS AND PROPERTIES OF MATTER.

I.—Matter, and our Knowledge of it ... 1
II.—Magnitude and Impenetrability ... 2
III.—Porosity and Density ... 3
IV.—Force ... 6
V.—Inertia, Gravity, and Weight ... 8
Sect. I.—Inertia ... 8
II.—Gravity ... 10
III.—Weight ... 15
VI.—Specific Gravity and Capillary Attraction ... 19
Sect. I.—Specific Gravity ... 19
II.—Capillary Attraction ... 22
VII.—Laws and Properties of Bodies in Motion ... 24

MECHANICS.

VIII.—The Production and Application of Force ... 33
Machinery and the Mechanical Powers ... 33
IX.—The Sources of Power ... 40
X.—On the Strength of Materials used in the Arts, and their Application to Mechanical Purposes ... 47
Sect. I.—Strength of Materials ... 47
II.—Application of Materials for Architectural and Structural Purposes ... 48

THE PHENOMENA OF FLUIDS.

XI.—Hydrostatics and Hydraulics ... 56
Sect. I.—Hydrostatics ... 56
II.—Hydraulics ... 57
XII.—Pneumatics ... 58
Sect. I.—General Properties of Aëriform Fluids ... 58
II.—Atmospheric Air ... 59
III.—Pump and Barometer ... 68

ACOUSTICS.

XIII.—Origin and Transmission of Sounds ... 73
Sect. I.—Vocal and Musical Sounds ... 80
II.—Reflection of Sound ... 85

HEAT.

XIV.—Nature and Sources of Heat ... 88
Sect. I.—The Sun considered as a Source of Heat ... 90
II.—The Earth and Electricity considered as Sources of Heat ... 93

CHAPTER PAGE

Sect. III.—Chemical Action considered as a Source of Heat 94
IV.—Mechanical Action considered as a Source of Heat 96
V.—Vital Action considered as a Source of Heat 99
XV.—Communication of Heat 100
Sect. I.—Conduction 101
II.—Convection 108
III.—Radiation 112
XVI.—Phenomena and Production of Dew 114
XVII.—Reflection, Absorption, and Transmission of Heat 121
Sect. I.—Reflection of Heat 122
II.—Absorption of Heat 123
III.—Transmission of Heat... 127
XVIII.—Effects of Heat 128
Sect. I.—Expansion 128
II.—Liquefaction 143
III.—Vaporisation 144
XIX.—Ebullition and Evaporation 147
Sect. I.—Ebullition 147
II.—Evaporation 150
XX.—Steam 153
Sect. I.—The Steam Engine 157
XXI.—Ventilation... 169
XXII.—Solution and Crystallisation 175

METEOROLOGY.

XXIII.—The Atmosphere 185
XXIV.—Winds 188
Sect. I.—Constant Winds 190
II.—Periodical Winds 192
III.—Variable Winds 193
XXV.—Clouds 199
Sect. I.—Modifications of Clouds 204
II.—Mist and Fog 208
XXVI.—Rain, Snow, Hail, Frost 211
Sect. I.—Rain 211
II.—Snow 218
III.—Hail 219
IV.—Frost 220
XXVII.—Luminous Atmospheric Phenomena 223
Sect. I.—Meteorites 223
II.—Aurora Borealis 226
XXVIII.—Popular Opinions concerning the Weather 227

LIGHT AND ACTINISM.

XXIX.—Light 229
XXX.—Reflection of Light 236
XXXI.—Refraction and Absorption of Light 240
XXXII.—Colour 247
XXXIII.—The Organs of Vision 252
XXXIV.—Deceptions of Vision 256
XXXV.—Artificial Light 258

CHAPTER PAGE
XXXVI.—Double Refraction and Polarisation 259
XXXVII.—Actinism, or the Chemical Influence of Light 261

ELECTRICITY.

XXXVIII.—Nature and Production of Electricity 267
Electrical Machines 272
XXXIX.—Atmospheric Electricity 274
Sect. I.—Lightning 274
II.—Effects of Lightning 276
III.—Lightning Conductors 279
IV.—Thunder 281

GALVANISM.

XL.—Nature and Production of Galvanic Electricity 282
Sect. I.—Phenomena and Effects of Galvanic Electricity 285
II.—Thermo-Electricity... 289

MAGNETISM.

XLI.—Natural Magnetic Phenomena 289
XLII.—Electro-Magnetism 297

CHEMISTRY.

XLIII.—Chemical Forces and Agencies 303
XLIV.—Oxygen 308
XLV.—Hydrogen and Water 311
Sect. I.—Hydrogen 311
II.—Water 312
XLVI.—Nitrogen and its Compounds 317
Sect. I.—Nitrogen 317
II.—Composition and Chemical Properties of the Atmosphere 317
III.—Compounds of Nitrogen 319
XLVII.—Carbon and its Compounds 322
XLVIII.—Combustion, Respiration, and Nutrition 330
Sect. I.—Combustion 330
II.—Respiration 347
III.—Nutrition and Animal Heat 352
XLIX.—Phosphorus and Sulphur 356
Sect. I.—Phosphorus 356
II.—Sulphur 357
L.—Chlorine, Iodine, Fluorine, Silicium, Boron 360
Sect. I.—Chlorine 360
II.—Iodine and Fluorine 361
III.—Silicium and Boron 362
LI.—The Metallic Elements 367
Sect. I.—The Alkali Metals... 369
II.—Metals of the Alkaline Earths 371
III.—Aluminum... 373
IV.—The Heavy Metals 377

ORGANIC CHEMISTRY.

LII.—Constitution and Formation of Organic Bodies 386
LIII.—Vegetable Organisation and Production 387
LIV.—Fermentation, Putrefaction, and decay 394

CHAPTER PAGE

LV.—Animal Organisation and Productions 404
LVI.—Fats, Oils, Gums 408
LVII.—Perfumes and Odours 414

PHILOSOPHY OF MANUFACTURES.

LVIII.—Nature of Fibrous Substances 418
LIX.—Manufacture of Textile Fabrics 426
LX.—Dyeing and Calico Printing 431
LXI.—Printing, Engraving, and Lithography 433

AGRICULTURAL AND RURAL ECONOMY.

LXII.—Elementary Principles pertaining to Agriculture 439
Sect. I.—Manures 441
II.—Growth of Plants 443
III.—Propagation of Fruit-trees 449
IV.—Flowers and Weeds 452
V.—Draining 456

GEOLOGY.

LXIII.—Formation and Structure of the Earth's Crust 457
LXIV.—Existing and Recent Geological Changes 473
LXV.—The Diluvial and Tertiary Systems 488
LXVI.—The Chalk, the Oolite, and the New Red Sandstone 491
LXVII.—The Carboniferous, Old Red Sandstone, and Silurian Systems ... 494
LXVIII.—On the Progressive Development of Animal Life upon the Surface of the Earth 500
LXIX.—Economical Geology 505
Sect. I.—Metals 506
II.—Mines 510
III.—Stones 518
IV.—Springs 518
V.—Soil 522

MINERALOGY.

LXX.—Characteristics and Classification of Minerals 523
LXXI.—Crystallography 527

GEOGRAPHY OF PLANTS AND ANIMALS.

LXXII.—Distribution of Plants 532
Food Plants 535
LXXIII.—Distribution of Animals 538
Races of Man 541

SCIENCE POPULARLY EXPLAINED.

LAWS AND PROPERTIES OF MATTER.

CHAPTER I.

MATTER, AND OUR KNOWLEDGE OF IT.

Q. What is MATTER?

A. Matter is the general *name* which has been given to that substance, which, under forms infinitely various, affects the senses.

Q. How do we know that anything EXISTS?

A. Because our *senses* give us evidence of the fact.

Q. What are the SENSES?

A. They are the instruments, or means, by which the mind is enabled to determine the *existence*, and take cognisance of the *qualities* of material objects.

Q. How MANY senses are there?

A. *Five:* hearing, seeing, smelling, tasting, and feeling.

Q. Would a person deprived of all sensation, be conscious of any MATERIAL EXISTENCE?

A. He would not; for all knowledge of the material world is derived through the medium of the *senses*.

Q. Is the impression transmitted to the mind by each organ of sensation DIFFERENT?

A. It is; each organ of sense is adapted to receive a particular influence of matter; and is designed to convey to the mind immediate notice of some peculiar action. This is the more noticeable, when we consider that, however delicate its structure, each organ of sense is wholly insensible to every influence except that to which it is especially adapted; thus, the eye is never affected by *sound*, or the ear by *light*.

Q. What is meant by the term BODY?

A. Any distinct portion of *matter* perceived by the senses.

Q. What do we mean when we speak of the PROPERTIES or QUALITIES of a body?

A. The *powers* belonging to the body, which are capable of exciting in our mind certain sensations.

Q. Are there any PROPERTIES or QUALITIES that belong alike to all material bodies?

A. There are at least two, which are inseparable from matter, in whatever state, or in whatever form it may exist, viz., *magnitude* and *impenetrability*.

CHAPTER II.

MAGNITUDE AND IMPENETRABILITY.

Q. What is MAGNITUDE?

A. The property of occupying *space*. It is impossible to conceive of a portion of matter so minute as to have no magnitude.

Q. What do we mean by the term SIZE of a body?

A. The quantity of *space* a body occupies.

Q. What is the SURFACE of a body?

A. The *external limits* of its magnitude.

Q. What is the AREA of a body?

A. The quantity of *surface*.

Q. What is IMPENETRABILITY?

A. That quality of matter which precludes the possibility of two bodies occupying the *same space at the same time*. When bodies are said to be impenetrable, it is therefore meant, that one cannot pass through another without displacing some, or all, of the component parts of that other.

There are many instances of apparent penetration; but in all these, the parts of the body which seem to be penetrated, are only displaced. Thus, if a needle be plunged into a vessel of water, all the water which previously filled the space into which the needle enters, will be displaced; and the level of the water will rise in the vessel to the same height as it would by pouring in so much more water as would fill the space occupied by the needle.

Q. What is the FIGURE of a body?

A. Its *form* or *shape*, as expressed by its boundaries or terminating extremities.

Q. What is the VOLUME of a body?

A. The quantity of *space* included within its external surface.

The figure and volume of a body are entirely independent of each other. Bodies having very different figures may have the same volume; or, in like manner, bodies of the same figure may have different volumes. Thus, a globe, for example, may have ten times the volume of another globe, and yet have the same figure; or a globe and cylinder may have the same volume, with entirely different figures.

Q. What is an ATOM of matter?

A. A *particle* so minute, as to admit of no division. Atoms are conceived to be the first principles or component parts of all bodies.

Sir Isaac Newton thus expresses his belief respecting the atomic condition of matter:—"It seems to me," he remarks, "that God, in the beginning, formed matter in a solid mass of hard, impenetrable particles; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear, or break in pieces—no ordinary power being able to divide what God made one in the first creation."

Q. Practically, do we KNOW of any limit to the division of matter?

A. *We do not;* and yet many of the phenomena which the researches of those who have successfully examined the laws of nature have developed, render it highly probable that all bodies are composed of elementary parts which are indivisible and unalterable.

An ounce of gold may be divided into four hundred and thirty-two thousand million parts. Each of these parts will retain all the characters and qualities which are found in the largest masses of metal. It retains its solidity, texture, and colour; it resists the same agents, and enters into combination with the same substances.

Q. What is a MOLECULE of matter?

A. The word molecule is often used to signify *component parts* of a body so small as to escape sensible observation, but not ultimate atoms; each molecule being supposed to be formed of several atoms, arranged according to some determinate figure.

Q. What is a PARTICLE of matter?

A. The term particle is also used to express *small component parts* of matter, but is generally applied to those which are *not too minute* to be discovered by observation.

CHAPTER III.

POROSITY AND DENSITY.

Q. What are the PORES of a body?

A. No two particles of matter are supposed to be in actual contact with each other; and the openings or interstitial spaces between these particles are called *pores.*

Q. Are the pores of bodies ever VISIBLE to the eye?

A. In very many bodies they are easily recognised, as in a sponge, various animal and vegetable membranes (the skin, the rind of an orange), in wood, bread, &c. In other bodies, as the metals, stone, &c., they are not visible.

Q. What is the REASON that a sponge, a piece of wood or metal, can, by pressure, be made to occupy a smaller space than it did originally?

A. Because the particles of which the sponge, the piece of wood or metal, are composed, are by pressure brought more closely together, diminishing at the same time the pores and the space the body occupies.

Q. What, then, is COMPRESSIBILITY?

A. That quality of matter in virtue of which a body allows its volume or size to be *diminished*, without diminishing the number of atoms or material particles of which it consists.

Q. What reason have we for supposing that no two particles of matter are in ABSOLUTE CONTACT?

A. Because all known bodies, whatever may be their nature, are capable of having their dimensions reduced without diminishing the amount of matter contained in them; hence the space by which the volume may be diminished must, before diminution, consist of *pores.*

Q. What is DENSITY?

A. The proportion of the quantity of matter in a body to its magnitude. Thus, if of two substances one contains in a given space twice as much matter as the other, it is said to be *twice as dense.*

Q. What connection is there between the DENSITY of a body, and its POROSITY?

A. A body will be more or less dense according as its particles are near to or remote from each other; and hence it is evident that the

greater the density the *less* the porosity, and the *greater* the porosity the *less* the density.

Q. Why do we call LEAD heavy, and feathers LIGHT?

A. Because the amount of matter contained in a quantity of lead occupying a given space is much greater than in a quantity of feathers capable of occupying the same space. The original particles of matter which make up the composition of lead and feathers are also different, and in the lead are arranged in much nearer connection with each other than in the feathers.

Q. Gold and lead are metals of great density; their pores are not visible. Is there any PROOF of their existence besides the fact that they can be compressed?

A. Water can be forced mechanically through a plate of lead or gold without rupturing any portion of the metal. Mercury or quicksilver, confined in a dish of lead or gold, will soak through the pores, and escape at the bottom.

An interesting experiment was tried at Florence, Italy, nearly two centuries ago, which furnished a striking illustration of the porosity of so dense a substance as gold. A hollow ball of this metal was filled with water, and the aperture exactly and firmly closed. The globe was then submitted to a very severe pressure, by which its figure was slightly changed. Now, it is proved in geometry, that a globe has this peculiar property—that any change whatever in its figure necessarily diminishes its volume, or capacity. The result was, that the water oozed through the pores, and covered the surface of the globe, presenting the appearance of dew, or steam cooled by the metal. This experiment also proved that the pores of the gold are larger than the elementary particles of water, since the latter are capable of passing through them.

Q. How is water or any other liquid made PURE by filtering through paper, cloth, a layer of sand, rock, &c.?

A. The process of filtration depends on the presence of pores in the substance used as a filter, of such a magnitude as to allow a passage to the liquid, but to refuse it to those impurities from which it is to be disengaged.

Q. Why is not the substance suitable for the filtration of ONE liquid equally adapted for the filtration of ALL liquids?

A. Because the magnitude of the pores in different substances and of the impurities in liquids is different; and no substance can be separated from a liquid by filtration, except one whose particles are larger than those of the liquid.

Q. Why do bubbles RISE to the surface when a piece of sugar, wood, or chalk is plunged under water?

A. Because the *air* previously existing in the pores becomes displaced by the water, and rises to the surface as bubbles.

Q. What occasions the SNAPPING of wood or coal when laid upon the fire.

A. Because the air or liquid contained in the pores becomes expanded by heat, and bursts the covering in which it is confined.

Q. What are the SPARKS OF FIRE which burst from the WOOD?

A. Very small pieces of wood made *red hot*, and separated from the log by the *force of the air* when it bursts from its confinement.

Q. Why does LIGHT, POROUS WOOD make more snapping than any OTHER kind?

A. Because the pores are *very large*, and contain *more air* than wood of a *closer grain.*

Q. Why does GREEN WOOD make LESS SNAPPING than DRY ?

A. Because the pores being filled with *sap*, contain *very little air*.

Q. Why does DRY WOOD make MORE SNAPPING than green ?

A. Because the sap is *dried up*, and the pores are filled with *air* instead.

Q. Why does DRY WOOD BURN more easily than GREEN or WET wood ?

A. Because the pores of dry wood are *filled with air*, which supports combustion ; but the pores of green or wet wood are filled with *moisture*, which extinguishes flame.

Q. When is a body said to be ELASTIC ?

A. When, on being compressed by the agency of a mechanical power, it is capable of resuming its former dimensions with a certain force when relieved from the operation of the force which has compressed it. This property is called *elasticity*.

Q. Into how MANY classes may all natural bodies be divided ?

A. All the bodies we meet with on the earth may be divided into *three* great classes ; viz., *solids*, *liquids*, and *gaseous* or *aeriform* bodies; and each of these states in which bodies exist is called its *state of aggregation*.

Q. What is a SOLID ?

A. A solid is a body whose particles of matter are so close or dense that they *resist* the impression or penetration of other bodies. Hence the parts of solid bodies are not movable or easily displaced like those of liquids.

Q. What is a LIQUID ?

A. A liquid is a substance which, like water, manifests immediately to the touch but a very feeble resistance ; but quite sufficient, however, to indicate its presence, even when in a state of repose. A liquid cannot be grasped between the fingers like a solid body; neither can it be collected permanently in a heap, or made to assume any particular figure except that of the vessel in which it is enclosed.

Q. What is a GASEOUS or AERIFORM body ?

A. A gaseous or aeriform body is an elastic, and generally an invisible, fluid, which, like the air surrounding us, affords no evidence of its presence to the sense of touch when in repose. Gaseous or aeriform bodies may be confined in vessels, from whence they exclude liquids or other bodies, thus demonstrating their *existence*, though invisible, and also their *impenetrability*.

Q. In what respect does a gas DIFFER from a liquid ?

A. A liquid, like water, milk, syrup, &c., can be made to flow regularly *down an inclined plane*, but a gas cannot.

Q. Why is violent exertion NECESSARY in walking against a high wind ?

A. Because the invisible particles of matter of which the atmosphere is composed *press violently* against us in an opposite direction, and require to be displaced before we can proceed.

Q. How does the WIND cause a ship to sail through the water ?

A. The particles of air are driven against the *canvass* of which the sails are composed, and being unable to pass through, transmit their

motion to the sail and mast, and from thence to the hull of the vessel.

Q. When is a substance said to be PLASTIC?

A. When it possesses intermediate properties between a solid and a fluid. Pitch is an example of a plastic body: it presents the appearance of a solid, but will be found to be continually changing its form by the movement of its particles, when left free to move.

Q. When a sponge is placed in water, that liquid appears to penetrate it. Does the water really enter the SOLID particles of the sponge?

A. It does not; it only enters the *pores* or vacant spaces between the particles.

Q. When we plunge the hand into a mass of sand, do we PENETRATE the sand?

A. We do not; we only *displace* the particles.

Q. What is the science of PHYSICS?

A. The science of Physics comprehends those branches of human knowledge which treat of the *conditions of matter* not dependent on chemical combination, which we perceive around us, and of the operations of those agents which are ever active in producing those conditions.

CHAPTER IV.

FORCE.

Q. What is FORCE?

A. Force is whatever *produces* or *opposes* the production of motion in matter. Force, in its merely mechanical signification, is whatever produces motion or pressure.

Q. How many KINDS of forces are recognised?

A. *Two*—external and internal forces. These are subdivided into Animal force, Mechanical force, Weight, Elasticity, Attraction, Repulsion, Polar forces, or Magnetism.

Q. What is the difference between an EXTERNAL and INTERNAL force?

A. External forces act upon matter at *sensible* distances; internal (or molecular) forces act only upon the particles or molecules of matter at *insensible* distances.

Q. What is ATTRACTION?

A. It is the force manifested by the mutual *approach* or *cohesion* of bodies.

Q. What is COHESIVE attraction?

A. It is the force which *holds together* the atoms of bodies. Cohesion acts only between particles of matter of the same kind, and at distances which are not measurable, or, as they are termed, *insensible distances.*

Q. What are POLAR forces, or magnetism?

A. The forces which are exhibited by the mutual approach or adhesion of the *loadstone* and *iron.*

B. What is REPULSION?

A. It is the force manifest in the movement of bodies from each

other. Thus, if a piece of glass, having been briskly rubbed with a silk-handkerchief, touch successively two feathers, these feathers, if brought together, will move asunder.

Q. What is ADHESION?

A. Adhesion is attraction between particles of matter of different kinds acting at immeasurably small distances only, and uniting the dissimilar particles into one mass.

Q. Why do two pieces of perfectly smooth material, as plate-glass or marble, when laid upon each other, adhere with GREAT FORCE?

A. Because the force or influence of *attraction* binds the two surfaces together; other smooth surfaces present the same phenomena.

Q. Why is MORTAR used to fasten bricks together?

A. Because the adhesive attraction between the particles of the brick and the particles of mortar is so strong, that they unite to form one solid mass.

Q. Why is a bar of IRON stronger than a bar of WOOD of the same size?

A. Because the cohesion existing between the particles of iron is *greater* than that existing between the particles of wood.

Q. Why are the particles of a LIQUID more easily separated than those of a SOLID?

A. Because the cohesive attraction which binds together the particles of a liquid is much less strong than that which binds together the particles of a solid.

Q. Why will a small needle, carefully laid upon the surface of water, FLOAT?

A. Because its weight is not sufficient to overcome the cohesion of the particles of water constituting the surface; consequently, it cannot pass through them and sink.

Q. Why can many light insects walk upon the surface of water without SINKING, or becoming WET?

A. Because their weight is insufficient to overcome the cohesion of the particles of water, and break through the surface. In like manner, a cat will walk safely upon the surface of thin ice, when a man would break through.

Q. If you drop water and laudanum from the same vessel, why will SIXTY drops of the water fill the same measure as ONE HUNDRED drops of laudanum?

A. The cohesion between the particles of the two liquids is different, being greatest in the water. Consequently, the number of particles which will adhere together to constitute a drop of water is greater than in the drop of laudanum.

Q. Why is the prescription of medicine by DROPS an unsafe method?

A. Because, not only do drops of fluid from the same vessel, and often of the same fluid from different vessels, differ in size, but also drops of the same fluid, to the extent of a third, from different parts of the lip of the same vessel.

Q. Why is it DIFFICULT to pour water from a vessel which has not a projecting lip?

A. Because, in consequence of the attraction between the water and the sides of the vessel, the fluid has a tendency to run down along the inclined outside of the vessel, and not at once to fall perpendicularly.

Q. Upon what does the HARDNESS of a body depend?

A. Not, as is often supposed, upon the *density* of a body, but upon the *force* with which the atoms hold their places in some particular arrangement. Gold is much more dense than the diamond, yet the metal is soft, and the diamond the hardest body in nature.

Q. When is a body said to be BRITTLE?

A. When the cohesion among the atoms exists within such narrow limits, that a very slight change of position, or increase of distance among them, is sufficient to produce a rupture. Brittleness is the opposite of elasticity, and is a property of most very hard bodies. Some bodies, however, like glass, may be both brittle and elastic.

Q. When is a body said to be DUCTILE?

A. When it is capable of being *drawn into wire.* In ductile substances the atoms seem to have no more fixed relation of position than in a liquid, but yet they cohere very strongly.

Q. When is a body said to be PLIANT?

A. When the cohesion of the particles is not destroyed by a considerable change of their direction. The most pliant substances are animal and vegetable fibres and membranes, as silk, bladder, hemp, &c.

CHAPTER V.

INERTIA, GRAVITY, AND WEIGHT.

SECTION I.—INERTIA.

Q. What is INERTIA?

A. Matter is incapable of spontaneous change; and the term *inertia* (or *inactivity*) signifies the total absence of power in matter to change its state. A body endued with inertia cannot of itself, and independent of all external influences, commence to move from a state of rest; neither can it, when moving, arrest its own progress and become quiescent.

Q. When a CARRIAGE is in motion, drawn by HORSES, why is the same exertion of power in the horses required to STOP IT, as would be necessary to BACK IT, if it were at rest?

A. Because the *force* required to destroy motion in one direction is *equal* to that required to produce as *much motion in the opposite direction.*

Q. If a body is incapable by ITSELF of changing its state, why will not a BALL fired from a cannon continue to move on FOR EVER?

A. *Chiefly* on account of the resistance of the *air* or medium through which it passes, and the *attraction of the earth.*

Q. What do we mean by the term FRICTION?

A. In *mechanics*, it signifies the resistance which a moving body meets with from the surface on which it moves.

Q. Is it possible to construct any machine, or arrangement of matter, which will PERPETUALLY continue in motion?

A. It is not; because the operations of *gravity*, the *resistance of*

the medium through which the body moves, or the friction of the surfaces upon which the body rests, will, in a given time, destroy and terminate all motion. In addition to this, all materials which we employ in construction will, in the course of time, *wear out* by use, or *decay* by natural agencies.

Q. Do we know of any instances of perpetual motion in NATURE?

A. Yes; the various *planetary bodies* belonging to the solar system have been moving with undiminished velocity for ages past; and, unless prevented by the agency which governs all nature, will continue to move in the same manner for ages to come.

Q. If a coach, railway carriage, or boat, moving with speed, be suddenly STOPPED or RETARDED from any cause, why are the passengers, or the baggage carried, precipitated from their places in the DIRECTION OF THE MOTION?

A. Because, by reason of their *inertia*, they *persevere* in the motion which they shared in common with the body that transported them, and are not deprived of that motion by the same cause.

Q. Why will a PERSON, leaping from a carriage in rapid motion, fall in the direction in which the carriage is moving at the MOMENT his feet meet the ground?

A. Because his *body*, on quitting the vehicle, *retains* by its *inertia* the motion which it has in common with it. When he reaches the ground, this motion is destroyed by the resistance of the ground to the feet, but is retained in the upper and heavier part of the body; so that the same effect is produced *as if the feet had been tripped.*

Q. Why are horses obliged to make a much greater exertion to START a carriage, than afterwards to KEEP IT IN MOTION?

A. Because when a carriage is once put in motion upon a level road, with a determinate speed, the only force necessary to sustain the motion is that which is sufficient to *overcome the friction of the road;* but, at starting, a greater expenditure of force is necessary, inasmuch as not only the *friction* is to be overcome, but the *force with which the vehicle is intended to move* must be communicated to it.

Q. If a body in motion strikes another body of equal mass at REST, the two will move on together, but with only half the original velocity of the first. To what is this change due?

A. Because *one-half* of the velocity of the *first body* is expended in overcoming the *inertia* of the *second.*

"The language sometimes used to explain the property of inertia in popular works is eminently calculated to mislead the student. The terms resistance, and stubbornness to move, are faulty in this respect. Inertia implies absolute passiveness, a perfect indifference to rest or motion. It implies as strongly the absence of all resistance to the reception of motion, as it does the absence of all power to move itself."—LARDNER.

Q. When the sails of a ship are first spread to receive the FORCE or IMPULSE of the wind, why does not the vessel acquire her full speed at once?

A. Because it requires a little time for the *impelling force* to overcome the *inertia* of the *mass* of the ship, or its disposition to remain at rest.

Q. Why, when the sails are taken in, does the vessel continue to move for a considerable time?

A. Because the *inertia of the mass* is opposed to a change of state, and the vessel will continue to move until the resistance of the water overcomes the opposition.

Q. Why is a man standing carelessly in the STERN of a boat liable to fall into the water behind, when the boat begins to move?

A. Because his *feet* are pulled forward while the *inertia of his body* keeps it in the same position, and, therefore, behind its support. For a similar reason, when the boat stops, the man is liable to fall forwards.

SECTION II.—GRAVITY.

Q. What is GRAVITY?

A. The tendency of a mass of matter towards its central body. *Gravitation* is the tendency of all matter in the universe towards all other matter. *Terrestrial gravitation* is the attraction of a body towards the centre of the earth.

Q. In what respect does the ATTRACTION OF GRAVITATION differ from all other attractive force?

A. Because it is the *common property of all bodies;* since everything to which we can attach the idea of materiality is affected more or less by gravitation.

Q. Why does an APPLE loosened from the tree fall to the ground?

A. Because the *earth attracts* or *draws it* to itself.

Q. Since all bodies are attracted towards the earth, how does it happen that SMOKE and some other forms of matter display the contrary phenomena of ASCENDING from it?

A. Because the *smoke is lighter than the air, bulk for bulk,* and floats upon it. It is unable to advance, however, in the most minute degree, without displacing or thrusting downward portions of the atmosphere equal to its own bulk.

Q. Why does a CORK pressed beneath the water rise and float on the surface?

A. Because the *cork is lighter than an equal bulk of water,* and is pressed up and sustained by it in the same manner that the particles of smoke are sustained by the particles of air.

Q. Why does a BALLOON rise in the air?

A. Because it is filled with a *gas* which is lighter, bulk for bulk, than the air.

Q. How long will SMOKE continue to float above the surface of the earth?

A. Until its *particles, uniting, become heavier than the air,* when they descend in the form of small flakes of *soot.*

Q. As GRAVITATIVE ATTRACTION is the common property of all bodies, why is it that all bodies not fastened to the earth's surface do not come in contact?

A. On account of the overpowering influence of the earth's attraction, the mutual attraction of particular bodies on its surface is *neutralised or overcome.*

In some instances, however, this mutual attraction exhibits itself.

Q. Why do the BUBBLES in a CUP of TEA range round the SIDES of the CUP?

A. Because the cup *attracts them.*

Q. Why do all the LITTLE BUBBLES tend towards the LARGE ONES?

A. Because the large bubbles (being the superior masses) *attract them.*

Q. Why do the BUBBLES of a CUP OF TEA FOLLOW a TEA-SPOON?

A. Because the tea-spoon *attracts them.*

Q. Why are the SIDES of a pond covered with LEAVES, while the MIDDLE of the pond is quite CLEAR?

A. Because the shore *attracts* the leaves to itself.

Q. Why can you fill a dry glass beyond the level of the brim?

A. Because the mass of water in the glass holds the overplus back by the attraction of its particles.

Q. Is the attraction of the EARTH the same at all distances from its SURFACE or CENTRE?

A. No; the attraction of the earth for a body varies *inversely with the square of its distance from the centre.*

Q. How can this be illustrated?

A. In the following manner:—If the earth attracts a body with a certain force at the distance of *one mile*, it will attract with *four times the force at half a mile*, *nine times the force at one-third of a mile*, and so on in like proportion. On the contrary, it will attract with but *one-fourth of the force at two miles*, *one-ninth of the force at three miles*, *one-sixteenth of the force at four miles*, and so on as the distance increases.

Q. Do ALL BODIES attract each other equally?

A. They attract each other with forces proportioned to their *masses.*

Q. A FEATHER falls to the ground by the influence of the earth's attraction. Now, as all bodies attract each other, does the FEATHER ATTRACT OR DRAW UP THE EARTH in any degree towards itself?

A. It does, with a force proportioned to its mass; but as the mass of the earth is infinitely greater than the feather, the influence of the feather is infinitely small, and we are unable to perceive it.

Q. What would be the consequence if the FEATHER DID NOT ATTRACT THE EARTH?

A. If *any portion* of the earth, however small, *failed* to attract another portion, and not be itself attracted, the *axis of the earth would be immediately changed*, involving an alteration of climate, and the place of the ocean in its bed.

Q. Why is it more dangerous to fall from a lofty elevation than from a low one?

A. As the attraction of the earth varies inversely with the square of the distance, the *force* with which a falling body will strike the ground will increase in proportion to the height from which it has fallen.

Q. What do we mean by the CENTRE OF GRAVITY?

A. That *point* in a body about which, if supported, the whole body will balance itself.

Q. In what POSITION only can a BODY rest?

A. Only when its *centre of gravity* is supported; and until this is accomplished the body will move, and continue to do so, until it settles into a position in which the centre of gravity cannot sink lower.

Q. Why does a PERSON in rising from a CHAIR bend forward?

A. When a person is sitting, the centre of gravity is supported by the *seat;* in an erect position, the centre of gravity is supported by the *feet;* therefore, before rising, it is necessary to change the centre of gravity, and by bending forward we transfer it from the chair to a point over the feet.

Q. Why does a QUADRUPED never raise both feet on the same side simultaneously?

A. Because, if it did, the centre of gravity would be unsupported, and the animal would fall over.

Q. Why is a TURTLE placed upon its BACK unable to move?

A. Because the centre of gravity of the turtle is, *in this position, at the lowest point*, and the animal is unable to change it; therefore it is obliged to remain at rest.

Q. Why does a person carrying a WEIGHT upon his BACK stoop forward?

A. In order to bring the centre of gravity of his body and the load over his feet.

If he carried the load in the position of the figure at A, he would fall backwards, as the direction of the centre of gravity would fall beyond his heels; to bring the centre of gravity over his feet, he assumes the position indicated by the figure B.

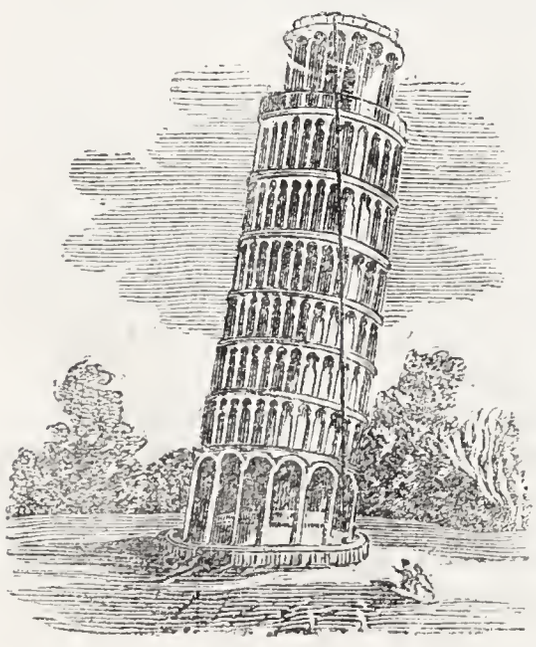
Fig. 1.

Fig. 2.

Q. Why is it more difficult to overthrow a body having a broad base, than one resting upon a narrow basis?

A. Because a body cannot fall over so long as a line directed from the centre of gravity vertically toward the surface upon which the body rests, falls within the figure formed by the base of the body in question. Hence, the *broader the base of a body, the more securely it will stand.*

Fig. 3.



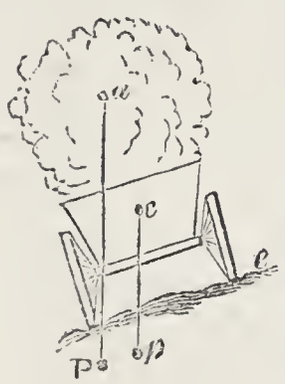
Q. How long will a WALL or TOWER stand securely?

A. So long as the perpendicular line drawn through its centre of gravity falls within its base.

The celebrated Leaning Tower of Pisa, 315 feet high, with an inclination from the perpendicular of 12 feet, is an example of this law. For instance, the line in *fig* 3, from the summit to the ground, passing through the centre of gravity, falls within the base, and the tower stands securely; but suppose an attempt was made to carry it a little higher, the perpendicular line passing through the centre of gravity would then fall without the base, and the structure could no longer support itself.

Q. Why is a HIGH CARRIAGE more liable to be overthrown by an irregularity of the road than a low one?

Fig. 4.



A. In a low carriage, *as in the case of a truck loaded with metal*, the centre of gravity is low, and the perpendicular line from it falls much within the base, as is shown by the line *c p* (*fig.* 4); but if the same truck be loaded with wool, the perpendicular let fall from the high centre of gravity would come very near to the wheel, as at *a P*, or altogether outside the wheels.

Q. Why is it more difficult to turn over a PYRAMIDAL-SHAPED STRUCTURE than a CYLINDRICAL ONE?

A. Before a structure will fall, *its centre of gravity must be elevated*, so that the perpendicular let fall from it will pass *beyond its base.* In a pyramid the centre of gravity is low, and the base broad; consequently, one side of the pyramid must be raised high up before it can be overthrown. In a cylinder the opposite conditions exist.

Q. What is the advantage of TURNING OUT THE TOES when we walk?

A. It increases the *breadth of the base* supporting the body, and enables us to stand more securely.

Q. Why do very FAT PEOPLE throw back their HEAD and SHOULDERS when they walk, with an air of apparent self-satisfaction?

A. In order that they may effectually keep the centre of gravity of the body over the base formed by the soles of the feet.

Q. Why cannot a MAN, standing with his HEELS close to a perpendicular wall, bend over sufficiently to pick up any object that lies before him on the ground, without falling?

A. Because the wall prevents him from throwing part of his body backward, *to counterbalance the head and arms* that must project forward.

Q. What is the reason that persons walking ARM-IN-ARM shake and jostle each other, unless they make the movements of their feet to correspond, as soldiers do in marching?

A. When we walk at a moderate rate, the centre of gravity comes alternately over the right and over the left foot. The body advances, therefore, in a *waving line;* and unless two persons walking together keep step, the waving motion of the two fails to coincide.

Q. Where would the CENTRE OF GRAVITY be in a WHEEL made entirely of wood, and of a uniform thickness?

A. In the *centre.*

Q. Where would the centre of gravity be if a PART of the RIM of the same wheel were made of IRON?

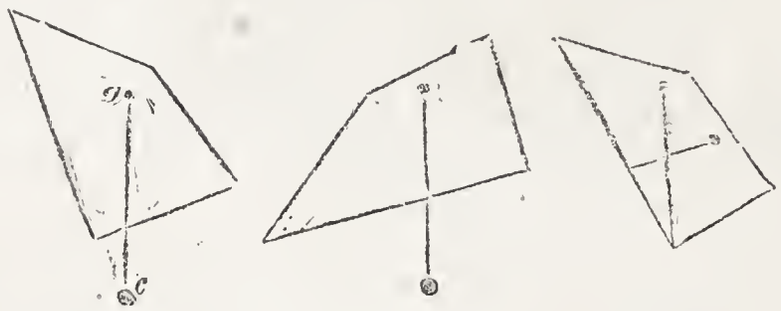
A. It would be changed to some point *aside* from the centre of the wheel.

Q. How can you find the centre of gravity in an IRREGULARLY-SHAPED body?

A. First suspend it from a point, as at *a* (*fig.* 5), and at the same point suspend a plumb-line *c*, when both board and line will hang in the position represented in the figure. Having marked this line, let

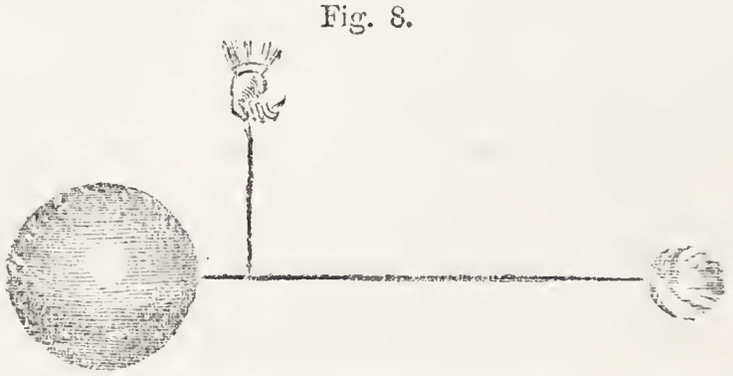
it be suspended from another and different point, as in *fig.* 6, and the perpendicular line indicated by the plumb again marked. The point where these two lines so marked cross each other is the centre of gravity of the body, as seen in *fig.* 7.

Fig. 5. Fig. 6. Fig. 7.



When two or more bodies are connected together, the centre of gravity of the two is the point on which they will balance without falling. Thus, if two balls, each weighing four pounds, be connected together by a bar, the centre of gravity will be a point on the bar equally distant from each. But if one of the balls be heavier than the other, then the centre of gravity will, in proportion, approach the larger ball. This is illustrated by reference to *fig.* 8, in which the centre of gravity about which the two balls support themselves, is seen to be nearest to the heaviest and largest ball.

Fig. 8.



Q. What is a PLUMB-LINE or PLUMMET?

A. It is a line with a weight attached to its end, used to determine a perpendicular, or to ascertain, *by comparison*, whether any other object is in a perpendicular position.

Q. When a LINE with a weight attached to its end is left to hang free, in what DIRECTION will its LINE OF DIRECTION be?

A. Its *line of direction* will be towards the centre of gravity in the earth.

Q. What is the PLUMB-RULE used by BUILDERS, MASONS, &c.

A. It is a narrow board, having a plumb-line suspended from its top, and a perpendicular mark through its middle.

Q. How by the use of the PLUMB-RULE can we ascertain whether the wall of a building is perfectly perpendicular?

A. If the wall be perfectly perpendicular and true, when the plumb-rule is placed against it, the plumb-line suspended from the top will *coincide*, or *cover the perpendicular mark in the centre of the board.* If the wall is not perpendicular, the plumb-line will *not coincide* with the line, but *deviate* in some degree from it.

Q. In what does the art of balancing or walking upon a ROPE consist?

A. In keeping the centre of gravity in a line over the base upon which the body rests.

Q. What is the BASE upon which the HUMAN BODY rests or is supported ?

A. The *two feet* and the *space* included between them.

Q. Why is it a very difficult thing for CHILDREN to learn to walk ?

A. In consequence of the natural upright position of the human body, it is constantly necessary to employ some exertion to keep our balance, or to prevent ourselves from falling, when we place one foot before the other. Children, after they acquire strength to stand, are obliged to acquire this knowledge of preserving the balance, by experience. When the art is once acquired, the necessary actions are performed involuntarily.

Q. Why do YOUNG QUADRUPEDS learn to walk much sooner than CHILDREN ?

A. Because a body is tottering in proportion to its great *altitude* and *narrow base.* A child has a body thus constituted, and learns to walk but slowly because of this difficulty (perhaps in ten or twelve months), while the young of quadrupeds, having a *broad supporting base*, are able to stand and move about almost immediately.

Q. Are all the LIMBS of a TALL TREE arranged in such a manner, that the line directed from the centre of gravity is caused to fall within the BASE of the TREE ?

A. *Nature* causes the various limbs to shoot out and grow from the sides with as much exactness, in respect to keeping the centre of gravity within the base, as though they had been all arranged with the plumb-line. Each limb grows, in respect to all the others, in such a manner as to preserve a due balance between the whole.

SECTION III.—WEIGHT.

Q. What is WEIGHT ?

A. It is the *measure of force* with which a body is attracted by the earth. In an ordinary sense *it is the quantity of matter contained in a body, as ascertained by the balance.*

Q. To what is the WEIGHT of a body proportional ?

A. The *weight of a body* is always proportional to the *quantity of matter* contained in it.

Q. Why will a BALL of LEAD weigh more than a BALL of COTTON of the same size ?

A. Because the quantity of matter contained in the ball of lead is much greater than the quantity of matter contained in the ball of cotton. The attraction of gravitation being proportioned to the quantity of matter, it follows that the lead ball will be drawn towards the earth with a greater force (*i. e. will weigh more*) than the ball of cotton.

Q. A MAN of moderate weight upon the surface of the earth would weigh TWO TONS if transported to the surface of the SUN : why would he weigh more upon the surface of the sun than upon the surface of the earth ?

A. Because the attractive force of the sun, on account of its greater magnitude, far exceeds the attractive force of the earth.

Weight, it must be remembered, is the measure of the attraction of gravitation.

Q. Why will a MASS of IRON weigh less on the top of a HIGH MOUNTAIN than at the LEVEL of the SEA ?

A. Because the attraction of gravitation is less at the top of the

mountain than at the level surface of the earth; weight decreasing or increasing as the attraction of gravitation increases or decreases, *according to the squares of the distances.*

A ball of iron, weighing a thousand pounds at the level of the sea, would be perceived to have lost two pounds of its weight if taken to the top of a mountain four miles high, a spring balance being used.

Q. Where will a BODY weigh the most on the surface of the EARTH?

A. At the poles of the earth, for at these points the attractive power is greatest.

It must be remembered that the earth is not a perfect sphere, but flattened at the poles; consequently the poles of the earth are nearer the centre of attraction (*i. e.* the centre of the earth) than at any other point on its surface.

Q. Where will a BODY weigh the least on the earth's surface?

A. At the *equator*, for there the attractive power is less; the surface at this point being the most distant from the centre of the earth.

Q. What would be the weight of a body carried to the CENTRE of the earth?

A. It would have no weight; for the attraction of gravitation, acting equally in every direction, no effect would be produced; and the body would be fixed as if sustained by a number of magnetic points.

Q. What two SYSTEMS of weight are employed in Great Britain?

A. *Troy* weight and *avoirdupois* weight.

Q. What is TROY weight used for, and from whence does it derive its name?

A. Troy weight is used for weighing gold and silver. It derives its name from the ancient designation of London, *Troy Novant*, or from *Troyes*, in France, where it was first adopted in Europe. It has existed in England from the time of Edward the Confessor.

Q. What is AVOIRDUPOIS weight used for, and from whence does it derive its name?

A. *Avoirdupois weight* is used for the weight of merchandise other than the precious metals. It derives its name from the French *avoirs* (*averia*), goods or chattels, and *poids*, weight.

Q. What is a GRAIN weight?

A. A *grain weight* is the smallest measure of weight made use of in the English system. By a law of England, enacted in 1286, it was ordered that 32 grains of wheat, well dried, should weigh a pennyweight. Hence the name *grain* applied to this measure of weight. It was afterwards ordered that a pennyweight should be divided into only 24 grains.

Q. How do we make a GRAIN WEIGHT for practical purposes?

A. By weighing a thin plate of metal of uniform thickness, and cutting out, by measurement, such a proportion of the whole as should give one grain. In this way, weights may be obtained for chemical purposes, which weigh only $\frac{1}{1000}$th part of a grain.

Q. How is the LENGTH or STANDARD of an inch, in the English standard of weights and measures, determined?

A. It has been found that a *pendulum* which, in the latitude of London, will vibrate or swing from the highest point on one side to the highest point on the other side in one second of time, will always, under the same circumstances, have a constant length. The *length of this pendulum* is divided into 391,393 equal parts; and 10,000

of these parts are called an inch, 12 of which make a foot, and 36 of them a yard.

Q. Are all the other measures determined from this STANDARD ?

A. They are; and by referring to this *standard*, we are enabled to verify or determine the accuracy of any particular weight or measure.

Q. What part of an INCH is a LINE ?

A. *One-twelfth of an inch* is designated as a line.

Q. How is the measure of a GALLON obtained ?

A. A cubic inch (*accurately obtained from the pendulum*) of distilled water, of a temperature of 62° Fahrenheit's thermometer, is taken and weighed. This weight is divided into 252,458 equal parts; and of these 1,000 will be a *grain*. Ten pounds, or 7,000 of these grains of distilled water, at the same temperature, will be a *gallon;* which gallon will contain 277 cubic inches, and about one-quarter of a cubic inch over.

Q. What is the most PERFECT SYSTEM of weights and measures existing and in use ?

A. The *French system*. This system is characterised by its great simplicity, all its divisions being made by 10. Hence, it is called the *decimal system* of weights and measures.

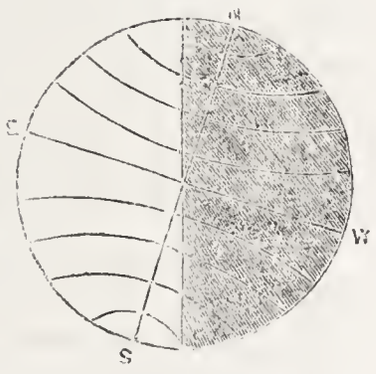
Q. WHEN was this system of weights and measures constructed ?

A. In 1788, the *French government*, feeling the necessity of having some *standard* by which all weights and measures might be compared and made uniform, ordered a scientific inquiry to be made; the result of which was the establishment of the present system of *French weights and measures*, which, from its perfect accuracy and simplicity, must ultimately take the place of all other systems.

Q. What did the French take as their UNIT or STANDARD ?

A. The French standard is based on an *invariable dimension of the globe*, which is recognised in all countries; viz., a *fourth part of the earth's meridian.*

Fig. 9.



Q. How are the different localities on the earth defined ?

A. By imaginary lines or circles drawn round it.

Q. What are those circles CALLED which run round the globe from EAST to WEST ?

A. *Parallels*, or *circles of latitude.* The largest of these, as will be seen by reference to *fig.* 9, is the *equator* E. W.

Q. What are those CIRCLES CALLED which run round the globe from NORTH to SOUTH ?

A. *Meridians*, or *circles of longitude.* They run round the globe lengthwise, and unite with each other at the poles.

Q. How do the CIRCLES OF LATITUDE differ from the CIRCLES OF LONGITUDE, or the MERIDIANS.

A. The circles of latitude gradually become *smaller* as they approach the poles, while the meridians, on the contrary, are all of *equal size.* The circle N E S W N (*fig.* 9) represents a meridian. A fourth part of this circle, or, what is the same thing, a fourth part

of the earth's circumference, as N E, is taken as the *basis* of the French system.

Q. What is the UNIT of length in the French system corresponding to the English inch?

A. The *metre*, found by dividing one-fourth part of the meridian into 10,000,000 equal parts. A single ten-millionth part is a *metre*. It is *equal* to about 39 English inches.

Q. How are the SMALLER MEASURES produced from the METRE?

A. By *dividing* by *ten*. The measures so obtained are designated by *Latin terms:* thus, a *decimetre* is the one-tenth of a metre; a *centimetre* is one-hundredth of a metre; a *millimetre* is one-thousandth of a metre.

Q. How are the LARGER MEASURES produced from the METRE?

A. By *multiplying* by *ten*. The measures so obtained are designated by *Greek terms:* thus, a *decametre* is 10 metres; a *hectometre* is 100 metres; a *kilometre* is 1,000 metres; a *miriametre* is 10,000 metres.

Q. How is the French system of WEIGHTS derived from the MEASURES OF LENGTH?

A. A *cubical box* was taken, measuring exactly on each of its sides the 100th part of a metre, or one centimetre. This was filled with water at its greatest density, and the weight of this water was called a *gramme*.

Q. How are the SMALLER and LARGER weights derived from the GRAMME?

A. By *multiplying* it or *dividing* it by *ten*, designating the smaller weights by Latin terms, and the larger by Greek terms. Thus, we have a *centigramme*, the one-hundredth part of a gramme, and the *hectogramme*, equal to 100 grammes.

Q. How is the standard for DRY MEASURE obtained in this system?

A. A *cube*, measuring on each of its sides one metre, constitutes a *stere*, or the unit of *dry measure*. The larger or smaller measures are obtained by multiplying or dividing this by ten.

Q. WHERE are the standards of weights and measures to be found in England?

A. At the Exchequer, in London, and in the keeping of the chief magistrates in the towns and cities of the kingdom.

Q. Are the standards of weights and measures in the United States the same as in England?

A. They are essentially the same.

Q. In what countries is the FRENCH SYSTEM adopted?

A. In *France* and *Belgium;* and by *scientific men* in all parts of the world.

CHAPTER VI.

SPECIFIC GRAVITY AND CAPILLARY ATTRACTION.

SECTION I.—SPECIFIC GRAVITY.

Q. Why does ICE float upon WATER?

A. Because it is *lighter* than water.

Q. Why does IRON sink in WATER?

A. Because it is *heavier* than water.

Q. If we put a piece of ICE in ALCOHOL, it sinks; if we put a piece of IRON upon QUICKSILVER, it floats: why is this?

A. Because the *ice is heavier* than the alcohol, and the *iron is lighter* than the quicksilver.

Q. What do we mean when we say that ICE is lighter than IRON?

A. We mean that, taking *equal bulks* of each, the former weighs less than the latter; and when we say that quicksilver is heavier than water, we mean that, in *equal volumes*, as a pint, for instance, the quicksilver has a greater weight than the water.

Q. How do we determine the SPECIFIC WEIGHT OR GRAVITY of spirits and ice, and iron and quicksilver; or, in other words, how do we ascertain how much LIGHTER the first two, and how much HEAVIER the last two are than WATER?

A. By dividing the *weight* of a *given bulk* of each of these substances by the *weight* of an *equal bulk* of *distilled water*.

Suppose we take five vessels, each of which would contain exactly one hundred grains of water, and fill them respectively with spirits, ice, water, iron, and quicksilver. The following differences in weight will be found:—The vessel filled with spirits would weigh 80 grains; with ice, 90 grains; with water, 100 grains; with iron 750 grains; with quicksilver, 1,350 grains. To facilitate the comparison of the numbers which indicate how much greater the specific gravity of one is than that of another, *water* has been fixed upon as the *standard* or *unit*. Therefore, in the above case, the question is, how much lighter than water are spirits and ice, and how much heavier than water are iron and quicksilver; or, in other words, how many times is 100 contained in 80, 90, 750, and 1,350? The other numbers are therefore to be divided by 100, the weight of the water; and there is found for spirits the weight 0·80, 1-5th lighter than water; for the ice 0·90, 1-10th lighter than water; for the iron 7·50, or 7½ heavier than water; for the quicksilver 13·50, or 13½ times heavier than water. *These numbers*, therefore, are the *specific gravities* of the *spirits*, *ice*, *iron*, and *quicksilver*.

Q. What, then, is SPECIFIC GRAVITY?

A. It is the *weight* of a body compared with the weight of an *equal bulk* of water.

Q. How does it differ from ORDINARY OR ABSOLUTE WEIGHT?

A. In *absolute weight* no regard is paid to the *volume* or *bulk* of substances. In specific weight, a given bulk or volume is compared with an equal volume or bulk of water.

Q. What body has the GREATEST specific weight?

A. *Purified platina*, which is 22 times heavier than an equal bulk of water.

Q. What substance has the SMALLEST specific weight?

A. *Hydrogen gas*, being 0·00008 lighter than an equal bulk of water.

Q. Why will an EGG float in STRONG BRINE, and not in FRESH WATER?

A. Because the solution of a solid in any liquid increases its *density*

or its *specific gravity;* the addition of salt to the water renders the specific gravity of the brine greater than that of fresh water, or of the egg.

Q. How do cooks ascertain if their BRINE be SALT ENOUGH for pickling?

A. They put an *egg into their brine.* If the egg *sinks;* the brine is *not strong enough;* if the egg *floats*, it *is.*

Q. Why will an EGG SINK if the brine be NOT STRONG enough for pickling?

A. Because an egg will be the *heavier;* but if as much *salt* be added as the water can dissolve, an egg will be lighter than the strong brine, and consequently float on the surface.

Q. Why is it more easy to SWIM in the SEA than in a RIVER?

A. Because the *specific gravity* of salt water is *greater* than that of fresh, and, therefore, it *buoys* up the swimmer better.

Q. Why do persons SINK in water when they are UNSKILFUL SWIMMERS?

A. Because they struggle to keep their *head out of water.*

Q. EXPLAIN how this is.

A. When our head is thrown back boldly into the water, our mouth is kept *above the surface*, and we are able to breathe; but when the head is kept *above the surface* of the water, the chin and mouth sink *beneath* it, and the swimmer is suffocated.

This may be illustrated thus:—If a piece of wood be of such specific gravity that only *two square inches* can float out of water, it is manifest that if two *other* inches are raised out, the two *former* inches must be plunged *in.* The body (in floating) resembles this piece of wood. If two square inches of our *face* float out of the water, we can breathe; but if part of the *back* and *crown* of the head are raised above the water, the lower part of the face will be depressed beneath it.

Q. Why can QUADRUPEDS swim MORE EASILY than MAN?

A. 1. Because the *trunk* of quadrupeds is *lighter* than water, and this is the greater part of them; and

2. The *position* of a beast (when swimming) is a *natural* one.

Q. Why is it MORE DIFFICULT for a MAN to swim than for a BEAST?

A. 1. Because his body is more heavy in proportion than that of a beast, and

2. The position and muscular action of a *man* (when swimming) differ greatly from his ordinary habits, but beasts swim in their ordinary position.

Q. Why can FAT men SWIM more EASILY than SPARE men?

A. Because *fat is lighter than water;* and the *fatter* a man is, the more *buoyant* will he be.

Q. How are FISHES able to ASCEND to the SURFACE of water?

A. Fishes have an *air-bladder* near the abdomen; when this bladder is *filled with air*, the fish increases in size, and (being lighter) ascends through the water to its surface.

Q. How are fishes able to DIVE in a minute to the BOTTOM of a stream?

A. They *expel the air* from their air-bladder; in consequence of which their *size is diminished*, and they sink instantly.

Q. Why does the body of a DROWNED person rise and float upon the surface several days after death?

A. Because, from the *accumulation of gas* within the body (caused

by incipient putrefaction), the body becomes specifically lighter than water, and rises and floats upon the surface.

Q. How are LIFE-BOATS prevented from sinking?

A. They contain in their sides *air-tight cells*, or *boxes* filled with air, which, by their buoyancy, prevent the boat from sinking even when it is filled with water.

Q. The SLAVES of the WEST INDIES have a plan of stealing RUM from a CASK, by inserting the LONG NECK of a BOTTLE, full of water, through the BUNG. How are they enabled in this manner to obtain the rum?

A. The *rum* is very much *lighter* than the *water;* and as the *heavy water* falls out of the bottle into the cask, the *lighter rum* rises to take its place.

Q. Why does a SKY-ROCKET ascend when fired?

A. Because the *lower part* is always producing a large quantity of *aeriform fluid*, which, in expanding, presses not only on the *air* below, but also upon the *rocket* above, and thus lifts it. The ascent is also aided by the recoil of the rocket from the part of its substance which is constantly bursting downward.

Q. Why does CREAM rise upon MILK?

A. Because it is composed of particles of *oily* or *fatty* matter, which are lighter than the *watery* particles of the milk.

Q. Why do STALE EGGS float upon water?

A. Because, by keeping, *air* is substituted for a portion of the *water* of the egg, which escapes.

Q. Why does not a VESSEL constructed of IRON sink, as the iron is much HEAVIER than the water?

A. Because the vessel is constructed in a *concave* form, and is thus rendered buoyant. Every substance becomes lighter in water, *in proportion to the amount of water displaced.* This is a law of nature: if it displaces less water than its weight in air, it sinks; if more, it floats. The ship, being concave, displaces a greater weight of water than the weight of the iron of which it is composed in the air.

A thick piece of iron, weighing half an ounce, loses in water nearly one-eighth of its weight; but if it is hammered out into a plate or vessel, of such a size that it occupies eight times as much space as before, it then loses its whole weight in water, and will float, sinking just to the brim. If made twice as large, it will displace one ounce of water, consequently, twice its own weight; it will then sink to the middle, and can be loaded with a half an ounce weight before sinking entirely.

Q. What is a HYDROMETER?

A. An instrument for determining the *specific gravity of liquids.* It is particularly used for determining the strength of spirituous liquors, it being inversely as their specific gravities; thus the less specific gravity of a liquor, the greater its strength.

By this instrument, the amount of water added to a given quantity of spirits can be determined with the utmost accuracy.

Q. Upon WHAT PRINCIPLE is the HYDROMETER constructed?

A. That the same body will sink to a greater or less depth in different liquids: *deeper in the lighter ones, and not so deep in those which are denser.* Advantage has therefore been taken of this, for constructing an instrument for determining the specific gravity of liquids.

Fig. 10.

Q. Of what does the HYDROMETER consist?

A. The *hydrometer* consists generally of a *hollow glass tube*, constructed, as is represented in *fig.* 10, with two *scales*, one to represent the density *b*, the other a thermometer, to represent the temperature *a*. The end of the tube is blown out into a bulb, which is loaded with quicksilver or shot, to cause it to float in a vertical position. The scale *b* shows the depth to which it sinks in any liquid. There are various instruments of this kind especially adapted for determining the density of spirits, oils, syrups, lye, &c.

Q. Why are STONES, GRAVEL, and SAND so easily moved by WAVES and CURRENTS?

A. Because the moving water has only to overcome about *half the weight* of the stone.

Q. Why can a STONE which on land requires the strength of TWO MEN to lift it, be lifted and carried in water by ONE MAN?

A. Because the *water holds up the stone* with a force equal to the weight of the volume of water it displaces.

Q. Why will some kinds of WOOD which float in WATER, sink in OIL?

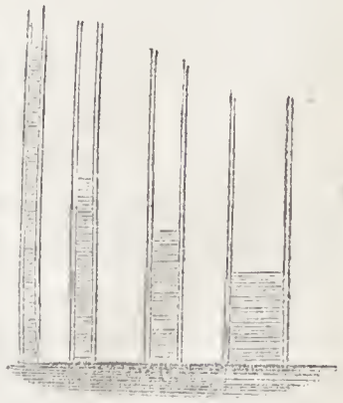
A. The wood, immersed either in oil or water, displaces exactly *its own bulk of the liquid.* In the water, the weight of the liquid displaced *is greater* than the weight of the wood; consequently, the water holds it up. In the oil, the weight of the liquid displaced *is less* than the weight of the wood; consequently, the oil is unable to sustain it, and the wood sinks.

SECTION II.—CAPILLARY ATTRACTION.

Q. What is CAPILLARY ATTRACTION?

A. The power which very minute tubes possess of causing a liquid to *rise in them above its level.*

Fig. 11.



"*Capillary,*" from the Latin word "capillaris," (*like a hair;*) the tubes referred to are almost as fine and delicate as a hair. Water ascends through a lump of sugar or piece of sponge, by capillary attraction.

N.B. The smaller the tube, the higher will the liquid be attracted by it. *Fig.* 11 illustrates the manner in which water will rise in tubes of different diameters.

Q. Why does WATER MELT SALT?

A. Because very minute particles of water insinuate themselves into the *pores* of the salt by *capillary attraction*, and force the crystals apart from each other.

Q. Why does WATER MELT SUGAR?

A. Because very minute particles of water insinuate themselves into the *pores* of the sugar by *capillary attraction*, and force the crystals apart from each other.

Q. Why is vegetation on the MARGIN of a river more luxuriant than in an open field?

A. Because the porous earth on the bank *draws up water* to the roots of the plants by *capillary attraction.*

Q. Why do persons who water PLANTS very often pour the water into the SAUCER and not over the plants?

A. Because the water in the saucer is *drawn up* by the mould (through the hole at the bottom of the flower-pot), and is transferred to the stem and leaves of the plant by *capillary attraction.*

Q. Why is COTTON best adapted for LAMP-WICKS?

A. Because the arrangement of the fibres of the cotton-wick is such, that the whole forms a *bundle of minute tubes*, in which the oil ascends and supplies the flame by *capillary attraction.*

Q. Why does BLOTTING PAPER absorb INK?

A. The *ink* is drawn up between the *minute fibres* of the paper by *capillary attraction.*

Q. Why will not WRITING OR SIZED PAPER absorb INK?

A. Because the *sizing*, being a species of glue into which writing papers are dipped, *fills up the little interstices between the fibres*, and in this way prevents all capillary attraction.

Q. How does a SPONGE absorb WATER?

A. The *pores* of the sponge constitute *minute tubes* in which the water rises by capillary attraction.

Q. What occasions the rise of water or other liquids in SMALL TUBES?

A. The *attraction* between the liquid and the walls of the tube.

Q. Why does the water rise higher in a tube of SMALL DIAMETER than in a LARGE one?

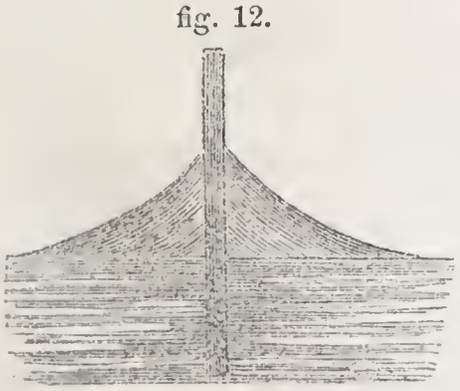
A. Because, in a small tube, the sides being nearer to the raised water, attract it more powerfully. *See fig.* 11.

Q. If we GREASE the INSIDE of a glass tube, will the water then rise in it?

A. It will not; because there is *no attraction between the grease and the water.*

Q. If we place a GLASS PLATE in water, will the liquid rise upon each side of it?

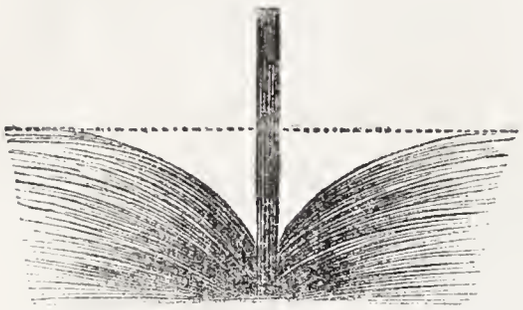
fig. 12.



A. If we place a glass rod or plate in a vessel of water, we shall perceive, after the whole has been allowed to remain free of any disturbance, that the water will rise to a higher level *on all sides of the glass*, than over any part of its surface. (*See fig.* 12.)

Q. If we place the SAME PLATE of glass in MERCURY, what will be the effect?

Fig. 13.



A. The *mercury*, instead of rising upon the sides of the glass, *will be depressed* (as shown in *fig.* 13), *there being no attraction between the glass and the mercury.*

Q. Why, in a BAROMETER, is the top of the column of mercury CONVEX or OVAL?

Fig. 14.

A. Because, owing to the *repulsion* between the glass and the mercury, the latter, when it comes in contact with the glass, is *depressed;* which leaves the central part of the top of the column of mercury the highest, as is shown in *fig.* 14.

Q. Why will WATER, INK, or OIL, coming in contact with the EDGE OF A BOOK, soak further in than if spilled upon the sides?

A. Because the *space between the leaves* acts in the same manner as a small tube would—attracts the fluid, and causes it to penetrate far inward. The fluid penetrates with more difficulty upon the *side of the leaf*, because the pores in the paper are irregular, and not continuous from leaf to leaf.

Q. Why does DRY WOOD, immersed in water, SWELL?

A. Because the *water enters the pores* of wood by capillary attraction, and *forces* the particles *further apart* from each other.

Q. Why may an IMMENSE MASS, suspended by a DRY ROPE, be raised a little way by merely WETTING the rope?

A. Because the *moisture* imbibed into the *substance of the rope* by capillary attraction, causes it to *swell laterally*, and to become shorter.

CHAPTER VII.

LAWS AND PROPERTIES OF BODIES IN MOTION.

Q. Will you define MOTION?

A. It is the term applied to the phenomena of the *changing of place among bodies.*

Q. What would be the state of things if NO MOTION existed?

A. The *universe* would be *dead.* There would be no rising and setting of the sun, no flow of water or of air (wind), no sound, light, or animal existence.

Q. The SURFACE of the EARTH at the EQUATOR moves at the rate of about a THOUSAND MILES in an HOUR: why are men not sensible of this rapid movement of the earth?

A. Because *all objects* about the observer *are moving in common*

with him. It is the natural uniformity of the undisturbed motion which causes the earth and all the bodies moving together with it upon its surface to appear at rest.

Q. How can you easily see that the EARTH is in motion?

A. By looking at some object that is entirely *unconnected* with it, as the *sun* or the *stars*. We are here, however, liable to the mistake that the sun or stars are in motion, and not we ourselves with the earth.

Q. Does the SUN really RISE and SET each day?

A. The sun maintains very nearly a constant position; but the earth revolves, and is constantly changing its position. *Really, therefore, the sun neither rises nor sets.*

Q. Why, to a PERSON SAILING in a BOAT on a smooth stream, or GOING SWIFTLY in a CARRIAGE on a smooth road, do the trees or buildings on the banks or roadside appear to move in an OPPOSITE DIRECTION?

A. The *relative situation* of the trees and buildings to the person, and to each other, is actually changed by the motion of the observer; but the mind, in judging of the real change in place by the difference in the position of the objects observed, *unconsciously* confounds the apparent and relative motion with that which is real and true.

Q. Upon what does the FORCE and IMPETUS of a BODY in MOTION depend?

A. Upon its *mass* and *velocity.*

Q. In what way may a SMALL BODY in motion be made to act with the SAME FORCE as another body of much GREATER PROPORTIONS?

A. By giving to the small body *a velocity as much greater* than that of the large one, *as the mass of the latter exceeds* that *of the former.*

Q. How may a PIN-CUSHION, weighing half an ounce, be made to produce as great an effect as a CANNON-BALL, weighing thirty-six pounds?

A. By giving to the *pin-cushion* 1,152 *times the velocity of the cannon-ball;* for 1,152 half-ounces being equal to 36 pounds, it must be apparent that the velocity of the pin-cushion would be just so much greater than the velocity of the cannon-ball, as the mass of the latter would be greater than that of the former.

Q. Why will a TALLOW CANDLE, fired from a gun, pierce a BOARD or TARGET in the same manner as a LEADEN BULLET will, under similar circumstances?

A. When a candle starts from the breech of a gun, its motion is gradually increased until it leaves the muzzle at a high velocity, and when it reaches the board or target, *every particle of matter composing it* is in a state of intense velocity: at the moment of contact the particles of matter composing the target are at rest, and as the density of the candle, multiplied by the velocity of its motion, is greater than the density of the target at rest, *the greater force overcomes the weaker*, and the candle breaks through, and pierces a hole in the board.

Q. Why, with an ENORMOUS PRESSURE and SLOW MOTION, can you not force a candle through a board?

A. Because the candle, on account of its slow motion, does not possess *sufficient momentum* to enable the density of its particles to

overcome the greater density of the board; consequently, the candle is itself mashed, instead of piercing the target.

Q. Why will a LARGE SHIP, moving towards a wharf with a motion hardly perceptible, crush with great force a BOAT intervening?

A. Because the great mass and weight of the vessel *compensate* for its want of velocity of motion.

Q. Why will a bullet, fired against a door HALF OPEN, pass through the wood without moving the door on its hinges?

A. Communication of motion from one body to another *is never instantaneous, but requires some time:* the velocity of the bullet is so great that it penetrates the wood in a space of time *too limited* to admit of the momentum of the bullet being communicated to the door against which it strikes.

Q. How can we determine the velocity of a body moving uniformly?

A. By dividing the space passed through by the time consumed; thus, the velocity of a steamboat going eighteen miles in two hours, will be found to be nine miles an hour.

Q. The VELOCITY of a BODY being known, how can we find out the DISTANCE passed over in a given time?

A. By multiplying the *space by the time;* thus, the steamboat, with a velocity of nine miles an hour, will of course run twice nine miles in two hours, and forty-eight times nine miles in forty-eight hours.

Q. In WHAT DIRECTION would a stone fall, if dropped on the deck from the masthead of a vessel in motion?

A. The attraction of gravitation would tend to draw the stone downwards in a straight line, the motion of the vessel would tend to carry the stone forwards horizontally: the line in which the stone would fall would be *a mean between a straight and a horizontal line*, viz. *a diagonal.*

Q. What is CENTRIFUGAL FORCE?

A. It is that *force* which causes a revolving body to *fly from a centre.*

Q. Why does a STONE, discharged from a sling, MOVE FORWARDS, when the cord which retained it is loosened?

A. Because of the *centrifugal force* it has acquired by the whirling of the sling previous to the discharge.

Q. Why do GRINDSTONES or WHEELS, in rapid motion, not unfrequently break and fly to pieces with great violence?

A. Because the *centrifugal force*, generated by the rapid revolving motion, overcomes the cohesion of the particles, and thus causes them to *separate and fly from the centre.*

Q. Can almost all revolving bodies be broken by sufficient rotative velocity?

A. Yes; for the centrifugal force increases with the *rapidity of revolution*, and finally becomes too strong to be resisted by the *cohesive force* which binds the particles of the body together.

Q. How MUCH FASTER would the EARTH be required to revolve in order to make the CENTRIFUGAL FORCE equal to the ATTRACTION of GRAVITATION?

A. Seventeen times faster, or in eighty-four minutes, instead of

twenty-four hours: in this case, all bodies on the surface of the earth would be destitute of weight.

Q. What would be the consequence if the earth revolved around its axis in LESS TIME than EIGHTY-FOUR MINUTES?

A. Gravitation would be completely overpowered, and *all fluids* and *loose substances* would fly from the surface.

Q. When a VESSEL containing water is whirled rapidly round, why does not the WATER fall out when the VESSEL is UPSIDE DOWN?

A. Because the *centrifugal force*, tending to make the water fly from the centre, *overcomes or balances* the *attraction of gravitation*, which tends to cause the water to fall out.

Q. Why does a MAN or horse, in turning a CORNER rapidly, INCLINE INWARDS, or LEAN towards the corner?

A. Because the *centrifugal force*, produced by turning rapidly, tends to *throw him away from the corner;* therefore, he *inclines inwards* to counteract it.

Q. Why do WATER-DOGS give a SEMIROTARY MOVEMENT to their skin to free themselves from water?

A. Because in this way a *centrifugal force* is generated, which causes the drops of water adherent to them to fly off.

Q. Why does a HORSE in a CIRCUS RING lean towards the centre?

A. Because, when the horse moves round with the performer on the saddle, both the horse and the rider *incline continually towards the centre* of the ring, and the inclination increases with the velocity of the motion: by this inclination their weights counteract the effect of the centrifugal force.

Q. Why does a SPINNING-TOP stand?

A. Because, while the top is perfectly upright, *its peg or point*, being directly under its centre, *supports it steadily*, and, although turning so rapidly, has no tendency to move from the place; but if the top inclines at all, *the side of the peg*, instead of the very point, comes in contact with the floor, and the peg then becomes a *little wheel or roller* advancing quickly, and with its touching edge describing a curve somewhat as a skater does, until it becomes directly under the body of the top as before. It thus appears that the very fact of the top inclining causes the point to shift its place, so that it cannot rest until it come again directly under the centre of the top.

Q. Why is the COURSE of rivers rarely STRAIGHT, but SERPENTINE and WINDING?

A. When, from any obstruction, the river is obliged to bend, *the centrifugal force tends to throw away the water from the centre of the curvature*, so that when a bend has once commenced, it increases, and is soon followed by others. Thus, for instance, the water being thrown by any cause to the left side, it wears that part into a curve or elbow, and by its centrifugal force acts constantly on the outside of the bend, until the rock, or higher land, resists its gradual progress; from this limit, being thrown back again, it wears a similar bend to the right hand, and after that another to the left, and so on.

Q. If a COCK at the EXTREMITY of a PIPE be suddenly closed while water is running through, why is a NOISE and SHOCK produced?

A. Because the *forward motion* of the whole body of the water contained in the pipe being *instantly arrested*, and the momentum of a liquid being as great as that of a solid, the water strikes the cock with as much force as if it were a long bar of metal, or a rod of wood having the *same weight and velocity* as the water. Then, as a fluid presses equally in all directions, a leaden pipe of great length may be widened, or even burst in the experiment.

Q. A HEAVY COACH and a LIGHT WAGON came in collision on the road. A suit for damages was brought by the proprietor of the wagon. How was it shown that ONE of the VEHICLES was moving at an UNSAFE VELOCITY?

A. On trial, the persons in the wagon deposed *that the shock*, occasioned by coming in contact, was so great, that it *threw them over the head of their horse;* and thus lost their case by proving that the faulty velocity was their own.

Q. Why did the FACT that they were THROWN over the HEAD OF THE HORSE by coming in contact with the coach, prove that their velocity was GREATER than it ought to have been?

A. The coach stopped the wagon by contact with it, but the bodies of the persons in the wagon *having the same velocity as the wagon, and not fastened to it, continued to move on.* Had the wagon moved slowly, the distance to which they would have been thrown would have been slight. To cause them to be thrown *as far as over the head of the horse*, would require a great velocity of motion.

Q. Why does a PERSON who is about to LEAP over a DITCH or CHASM, first make a run of a little distance?

A. In order that the *impetus he acquires in running* may help him in the jump.

Q. Why is a STANDING LEAP always shorter than a RUNNING ONE?

A. Because in the running leap, in *addition to the force acquired by the contraction of the muscles*, we have added the *force of the motion* acquired by running.

Q. Why do we KICK against the door-post to SHAKE the snow or dust from our SHOES?

A. The forward motion of the foot is arrested by the impact against the post; but this is not the case with respect to the particles of dust or snow which are not attached to the foot; but the motion imparted to them, equally with the foot, is continued, and causes them to fly off.

Q. Why do we BEAT a coat or carpet to EXPEL the dust?

A. The cause which arrests the motion imparted to the coat or carpet by the blow does not arrest the particles of dust, and their motion being continued, they fly off.

Q. Why is the UP-AND-DOWN motion of carriages and vessels often beneficial to invalids?

A. In the long, upright veins below the heart, when the body falls, the blood by its inertia, and the supporting action of the vessels, does

not fall so fast as the body, and therefore really rises in the veins, and as there are valves in the vein preventing return, *the circulation is thus quickened* without any muscular exhaustion on the part of the individual.

Q. Why are persons made SICK at SEA by the MOTION of the VESSEL; also by SWINGING, &c.?

A. Because the motion of the vessel or swing imparted to the body is *not participated in* by the organs and fluids of the body, they being thus caused to move in an *involuntary manner*, produce nausea and sickness.

Q. Why do BIRDS fly?

A. Because they have the largest bones of all animals in proportion to their weight, and their bones are more hollow than those of animals that do not fly. Air-vessels also enable them to blow out the hollow parts of their bodies when they wish to make their descent slower, rise more swiftly, or float in the air. The muscles that move the wings of birds downwards, in many instances, are a sixth part of the weight of the whole body, whereas those of a man are not, in proportion, one-hundredth part so large.

Q. Why does FLYING differ from LEAPING?

A. Because flying is the continued suspension and progress of the whole body in the air, by the action of the wings. In leaping, the body is equally suspended in the air, but the suspension is only momentary. In flying, on the contrary, the body remains in the air and acquires a progressive motion by repeated strokes of the wings on the surrounding fluid.

Q. Why do BIRDS stretch out their NECKS when FLYING?

A. Because they may become like *sharp points*, dividing the air and diminishing the resistance.

Q. Why are the STRONGEST FEATHERS of birds in the PINIONS and TAIL?

A. Because, when the wing is expanded, the pinion-feathers may form, as it were, *broad fans*, by which the bird is enabled to raise itself in the air and fly, while its tail-feathers *direct its course.*

Q. Why can a person safely SKATE with GREAT RAPIDITY over ice which would not support his weight if he moved over it MORE SLOWLY?

A. From the fact that *time is required for producing the fracture of the ice*, as soon as the weight of the skater begins to act on any point, the ice, supported by the water, bends slowly under him, but if the skater's velocity is great, he has passed off from the spot which was loaded before the bending has reached the point which would cause the ice to break.

Q. It sometimes happens when PERSONS are KNOCKED DOWN by CARRIAGES, that the WHEELS pass over them with scarcely any injury, though if the WEIGHT of the CARRIAGE had rested on their body, EVEN FOR A FEW SECONDS, it would have crushed them to death. What explanation can be given of this fact?

A. The wheel moves with such rapidity that *the weight has not time sufficient to exert its full effect.*

Q. In a REVOLVING BODY, what is the AXIS of MOTION?

A. The *line* about which the body revolves.

Q. What is the CENTRE of MOTION in a REVOLVING BODY?

A. The *point* about which it moves.

Q. In a REVOLVING BODY or WHEEL, WHAT PART will have GREATEST VELOCITY, and the greatest CENTRIFUGAL FORCE?

A. The *part farthest* from the axis of motion.

Q. What is the MOMENTUM of a moving body?

A. The term *momentum* denotes the *absolute force of a moving body* with reference to the effect it is capable of producing.

Q. When TWO PERSONS STRIKE their HEADS together, one being in MOTION and the other at REST, why are both equally hurt?

A. Because, when bodies strike each other, *action and reaction are equal;* the head that is at rest returns the blow with equal force to the head that strikes.

Q. When an elastic BALL is thrown against the side of a house with a CERTAIN FORCE, why does it rebound?

A. Because the *side of the house* resists the ball with the *same force*, and the ball being elastic, *rebounds.*

Q. When the SAME BALL is thrown against a PANE of GLASS with the same force, it goes through, breaking the glass: why does it not rebound as before?

A. Because the glass has not sufficient power to resist the full force of the ball: it destroys a part of the force of the ball, but the remainder continuing to act, the ball goes through, shattering the glass.

Q. Why did not the MAN succeed who undertook to make a FAIR WIND for his PLEASURE BOAT, by erecting an IMMENSE BELLOWS in the STERN, and blowing against the SAILS?

A. Because the action of the stream of wind and the reaction of the sails were exactly equal, and, consequently, the boat remained at rest.

Q. If he had blown in a CONTRARY DIRECTION from the sails, instead of against them, would the boat have moved?

A. It would, with the *same force* that the air issued from the bellows-pipe.

Q. Why cannot a MAN raise himself over a FENCE by pulling upon the STRAPS of his BOOTS?

A. Because the *action of the force* exerted to raise himself is *exactly counteracted* by the reaction of the force which tends to keep him down.

Q. Why can a MAN raise himself in the AIR by PULLING upon a ROPE suspended above him?

A. Because the reaction of the force from the rope *is not equal* to the action of the force exerted in pulling by the muscles of the arms; *consequently the body rises.*

Q. Does a MAN in rowing DRIVE the WATER ASTERN with the SAME FORCE that he impels the BOAT FORWARDS?

A. He does: *action and reaction being exactly equal.*

Q. Why is it more dangerous to leap from a HIGH WINDOW than from a LOW TABLE?

A. Because the *velocity of a falling body*, and, consequently, the

force with which it will strike the ground, *increases with the distance* through which it falls.

Q. Why does the velocity of a falling body INCREASE with the distance through which it falls?

A. Owing to the *inertia of matter*, any force continuing to act upon a mass which is free to obey it, produces in it a *quickening* or *accelerated motion;* for, as the motion given in the first instant continues afterwards without any further force, merely on account of its inertia, it follows that as much more motion is added during the second instant, and as much again during the third, and so on. *A falling body, therefore, under the influence of the attraction of gravitation, receives every instant an increased velocity and momentum.*

Q. Why, in a WATERFALL or CATARACT, does the water at the EDGE of the FALL appear as a THICK MOVING MASS, and at the bottom of the fall, as a THIN SHEET, or as spray?

A. As the sheet of water descends, it becomes reduced in size, *because it increases in velocity;* the bulk diminishing from above downwards, in the same proportion as the velocity of the particles increases.

Q. How FAR will a body fall through the influence of gravity, in one SECOND of TIME?

A. Sixteen feet.

Q. How far will it fall in TWO SECONDS?

A. Four times 16 feet, or 64 feet; in three seconds it will fall 144 feet; in four, 256; in five seconds, 400 feet, and so on.

Q. What is the RULE by which the height from which a body falls may be found, the time consumed in falling being known?

A. Multiply the square of the number of seconds of time consumed in falling, by the distance which a body will fall in one second.

Q. If a STONE is FIVE SECONDS in falling from the top of a precipice, HOW HIGH is the precipice?

A. The *square* of five seconds is 25; this multiplied by 16, *the number of feet a body will fall in one second*, gives 400, the height of the precipice.

Q. What is a PENDULUM?

A. A *pendulum is a heavy body*, as a piece of metal, *suspended by a wire or cord*, so as to swing backwards and forwards.

Q. When is a PENDULUM said to VIBRATE?

A. When it swings backwards and forwards; and that part of the circle through which it vibrates is called its *arc.*

Q. What is a COMMON CLOCK?

A. Merely a pendulum, with wheelwork attached to it, to record the number of vibrations, and with a weight or spring, having force sufficient to counteract the retarding effects of friction and the resistance of the air.

Q. How does the SWING of the pendulum MARK TIME?

A. The *vibrations* of the pendulum are numbered by a wheel having *sixty teeth*, which revolves *once in a minute. Each tooth* answers to *one swing* of the pendulum, and the wheel moves forward

one tooth in a second. A *hand* fixed on the *axis* of this *wheel*, projecting through the *dial-plate*, will be the *second-hand* of the clock. The other wheels are so connected with the first, and the number of teeth on them is so proportioned, that one turns sixty times slower than the first, to fit its axis to carry a minute hand; and another, by moving twelve times slower still, is fitted to carry an hour-hand.

Q. How LONG must a pendulum be to beat SECONDS?

A. About 39 *inches.*

Q. Why does a COMMON CLOCK go FASTER in WINTER than in SUMMER?

A. Because the pendulum-rod becomes *contracted* by *cold* in winter, and *lengthened* by *heat* in summer.

Q. Why does a CHANGE in the LENGTH of the PENDULUM cause a clock to go FASTER or SLOWER?

A. The number of vibrations which a pendulum makes in a given time *depends upon its length*, because a long pendulum does not perform its journey to and from the corresponding points of its arc so soon as a short one.

Q. How does a WATCH differ from a CLOCK?

A. It has a *vibrating wheel* instead of a *vibrating pendulum.* This wheel, called the *balance-wheel*, is moved by a *spring*, which is always forcing it to a middle position of rest, but does not fix it there, because the momentum acquired during its approach from either side to the middle position, carries it just as far past on the other side, and the spring has to begin its work again. The *balance-wheel* at each vibration allows *one tooth* of the adjoining wheel to pass, as the pendulum does in a clock, and the record of the beats is preserved by the wheels which follow as already explained for the clock.

Q. A MAN receiving a HEAVY BLOW of a great HAMMER upon his CHEST would be killed by it; but if a HEAVY ANVIL be first laid upon the CHEST, and the blow then received upon the ANVIL, the man bears it with impunity: WHY IS THIS?

A. The quantity of motion in the hammer *being diffused through the great mass of the anvil*, produces but a trifling velocity, which the *elasticity of the chest*, in its slow yielding, easily overcomes.

Q. A LEADEN BULLET pressed slowly against a PANE of GLASS breaks it irregularly, where the strength happens to be the least; but the SAME BULLET, shot at it from a PISTOL, makes only a small round hole: EXPLAIN THE REASON OF THIS.

A. In the *latter case*, the force of the bullet is allowed to act against or resist the force of cohesion in the glass *for so short a time, owing to its rapid passage*, that it is not sufficient to affect any other part of the glass than the points against which it impinges. It has been amusingly said of such a case, by Dr. Arnott, "that the particles struck and carried away have not time to warn their neighbours of what is happening." In the first instance, a reverse action produces a contrary effect.

MECHANICS.

—•—

CHAPTER VIII.

THE PRODUCTION AND APPLICATION OF FORCE.

SECTION I.—MACHINERY AND THE MECHANICAL POWERS.

Q. What is the SCIENCE of MECHANICS?

A. *Mechanics* may be considered as the *Philosophy of Machinery*, or the science which investigates the laws and effects of motion.

Q. From what SOURCES do we derive advantages by the use of MACHINES and MANUFACTURES?

A. From the *addition* they make to human *power;* from the *economy* they produce of human *time;* from the *conversion* of substances apparently common and worthless into *valuable products.*

Q. How do MACHINES make ADDITIONS to human power?

A. They enable us to use the powers of *natural agents*, as *wind*, *water*, *steam;* they also enable us to use *animal power* with greater effect, as when we move an object easily with a lever, which we could not with the unaided hand.

Q. How do MACHINES produce ECONOMY of human time?

A. They accomplish with rapidity what would require the hand unaided much time to perform. A machine turns a gun-stock in a few minutes; to shape it by hand would be the work of hours.

Q. How do MACHINES CONVERT objects apparently worthless into VALUABLE PRODUCTS?

A. By their *great power*, *economy*, *and rapidity of action*, they make it profitable to use objects for manufacturing purposes which it would be unprofitable or impossible to use if they were to be manufactured by hand. Without machines, iron could not be forged into shafts for gigantic engines; fibres could not be twisted into cables; granite, in large masses, could not be transported from the quarries.

Q. What is a MACHINE?

A. By a machine we understand a *combination of mechanical powers* adapted to vary the direction, application, and intensity of a moving force, *so as to produce a given result.*

Q. What is the DIFFERENCE between A MACHINE and A TOOL?

A. The difference between *a machine and a tool* is not capable of very precise distinction. A tool is usually *more simple* than a machine: it is generally used *by hand*, while a machine is generally moved by *some other than human power.*

Q. Does a MACHINE ever CREATE POWER, or INCREASE the QUANTITY of POWER or FORCE applied to it?

A. A machine will enable us to *concentrate or divide* any kind or

quantity of force which we may possess, but they no more increase the quantity of force than a mill-pond increases the quantity of water flowing in the stream.

Q. How many kinds of motion are considered in machinery?

A. Two—*rotary* and *reciprocating*.

Q. What is ROTARY motion?

A. A rotary motion is that in which the moving parts *revolve round an axis*, as in a wheel, a crank, or a fly.

Q. What is RECIPROCATING MOTION?

A. A reciprocating or alternate motion is that in which a body *retraces its own path, or moves alternately backwards and forwards in the same track*, which may be curved, as in the beam of a steam-engine, or straight, as in the piston.

Q. In the application of machinery, what THREE THINGS are to be considered?

A. 1. The *force or resistance* which is required to be sustained, opposed, or overcome.

2. The *force* which is used to sustain, oppose, or overcome that resistance.

3. The *machine* itself, by which the effect of this latter force *is transmitted* to the former.

Of whatever nature be the force or the resistance which is to be sustained or overcome, it is technically called the *weight*, since, whatever it be, a weight of equivalent force may always be found. The force which is employed to sustain or overcome it is technically called the *power*.

Q. Into what THREE GREAT DIVISIONS may the mechanic powers be divided?

A. The *Lever*, the *Multiplied Cord*, and the *Inclined Plane*. To these some have added the *Wheel and Axle*, the *Pulley*, the *Wedge*, and the *Screw*, but these last are only modifications of the former powers.

Q. What MACHINES are included under the FIRST CLASS?

A. All which are composed of a *solid body revolving on a fixed axis*. In these the power and the weight are always supposed to be applied at right angles to the axis.

Q. What machines are included under the SECOND CLASS?

A. All those in which force is transmitted *by means of flexible threads*, *ropes*, or *chains*. Within this class are included all the various forms of pulleys.

Q. What MACHINES are included under the THIRD CLASS?

A. All those in which the weight or resistance *is supported or moved on a hard surface inclined to the vertical direction;* under this class are included the inclined plane, the screw, and the wedge.

Q. What is a LEVER?

A. An *inflexible bar* turning on an axis.

Q. What are the ARMS of a LEVER?

A. Those parts of the bar which extend on each side of the axis.

Q. What is its FULCRUM, or PROP?

A. Simply another term to designate the axis.

Q. How many kinds of LEVERS are there?

A. *Three;* divided according to the relative position of the *power*, the *weight*, and the *fulcrum*.

Q. What is a LEVER of the FIRST KIND?

Fig. 15.

A. In a lever of the first kind (as in *fig.* 15) *the fulcrum is between the power and the weight.*

Q. What are EXAMPLES of this form of LEVER?

A. A *crowbar*, applied to elevate a stone, is an instance; the *fulcrum* is another stone placed near that to be raised, and the *power* is the hand placed at the other end of the bar.

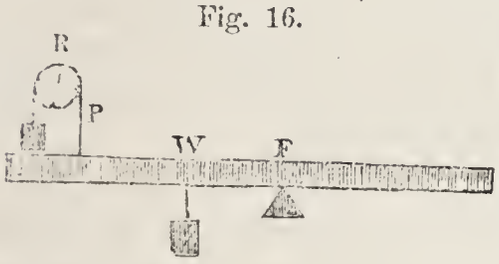
A *poker* applied to raise fuel is a lever of the first class, the *fulcrum* being the bars of the grate. The *brake* or *handle of a pump* is also a familiar example.

Q. What ORDER of LEVER is a PAIR of SCISSORS, PINCERS, NIPPERS, &c.?

A. Scissors, pincers, &c., are composed of two levers of the *first kind*, the *fulcrum* being the *joint* or *pivot*, and the *weight* the *resistance of the substance* to be cut or seized. The power of the figures is applied at the other end of the levers.

Q. What is a LEVER of the SECOND KIND?

Fig. 16.



A. In a lever of the second kind (as in *fig.* 16) *the weight is between the fulcrum and the power.* The power is represented as applied over the wheel R.

Q. What are EXAMPLES of THIS FORM of LEVER?

A. *Nut-crackers* are two levers of the second kind; the *hinge* which unites them being the *fulcrum*, the *resistance of the shell* placed between them being the *weight*, and the *hand, the power.* An oar is a lever of the second kind, in which the *reaction of the water* against the blade is the *fulcrum; the boat, the weight;* and the *hand of the boatman, the power.* A door moved on its hinges is another example.

Q. What sort of a LEVER is a WHEELBARROW?

A. One of the *second kind;* the *fulcrum* being the point at which the wheel presses upon the ground; *the barrow and its load*, the *weight;* and the *hands*, the *power.*

Fig. 17 represents the manner of using a hand-spike or bar as a lever of this first kind; *fig.* 18 shows how a similar bar may be employed as a lever of the second kind, the ground against which the point of the lever is fixed being the fulcrum.

Fig. 17.

Fig. 18.

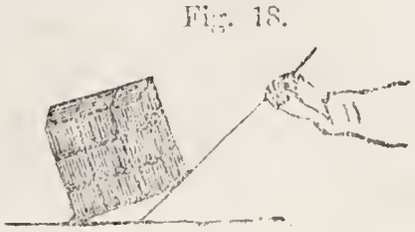
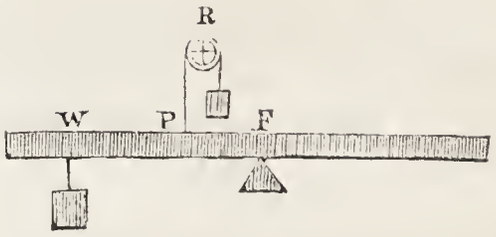


Fig. 19.

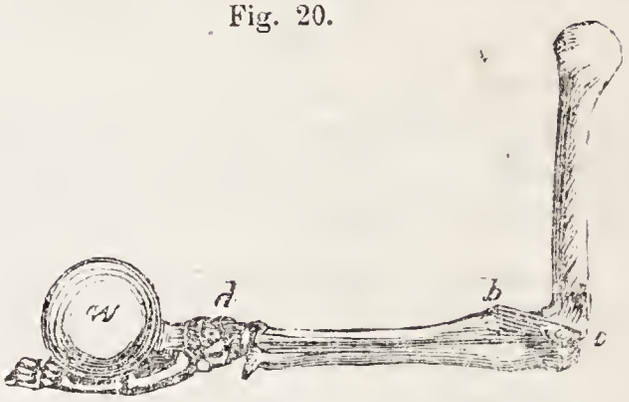


Q. What is a LEVER of the THIRD KIND?

A. In a lever of the third kind (as in *fig.* 19) the power is between the fulcrum and the weight.

Q. What are examples of this kind of lever?

Fig. 20.



A. The most striking example of levers of the third kind are found in the animal kingdom. The limbs of animals are generally levers of this description. The socket of the bone (*a*, *fig.* 20) is the fulcrum; a strong muscle *b* attached to the bone near the socket *c*, and extending to *d*, is the power; and the weight of the limb, together with whatever resistance *w* is opposed to its motion, is the weight.

Q. For what is this variety of lever generally used?

A. In cases where a quick motion is required, rather than great force: this effect is particularly conspicuous in the motions of the arms and legs of the human body; a very inconsiderable contraction of the muscles at the shoulders and the hips giving the sweep to the limbs from which the body derives so much activity.

Q. What sort of levers is a pair of tongs?

A. Levers of the third kind, in which the power is the hand placed immediately beneath the fulcrum, or the point where the two levers are connected. Shears used in shearing sheep, and the treadle of the turning-lathe, are other examples of levers of this order.

Q. Why do not BIRDS fall down in SLEEPING on their PERCH?

A. Because such is the structure of their feet and legs, that the *greater the weight upon the muscles*, the more firmly the claws grasp whatever they lay hold of.

Q. What kind of a LEVER is the FOOT and LEG of a BIRD?

A. A *lever of the third kind*, the body being the *weight;* the *muscle*, the *power;* and the *perch* or *roost*, the *fulcrum.*

Q. A BOY who cannot exert a force of fifty pounds, may by means of a CLAW-HAMMER, which is a lever of the first class, draw out a nail which would support the weight of half a ton: DOES NOT THE LEVER IN THIS CASE CREATE POWER?

A. No; because the hand of the boy is required to move through perhaps *one foot of space* to make the nail rise *one quarter of an inch.* It has been already shown that the force of a small body moving with great velocity may equal the force of a large body with a slight velocity. On the same principle, the small weight or power exerted by the boy on the end of the lever, moving through a large space

with an increased velocity, acquires sufficient momentum to overcome a much greater resistance at the short end of the lever.

Q. In the ordinary arrangements for WEIGHING, what MECHANICAL POWERS are employed?

A. Levers of the different orders, employed either singly or in combination. In the common balance, styled from its adventitious appendages *a pair of scales*, the *beam*, which is the essential part, is simply a *lever of the first order*, having equal arms, and turning freely on its fulcrum or centre of action.

Q. How in an ordinary balance may a FALSE WEIGHT be detected?

A. By changing the places of the weight and the article to be weighed; the equipoise before effected will then be destroyed.

Q. How are the so-called "HAY-SCALES" constructed?

A. They consist of a *system of levers* supporting a quadrangular floor. Four levers turning on their fulcrums, extend from the angles of a box beneath the floor towards its centre, where they are connected together, and also with another lever, extending across the middle of the box, and passing beyond its limits. This last lever acts upon a third, which presses on a spring or is connected with the arm of a balance, by which the amount of pressure on the whole floor may be ascertained.

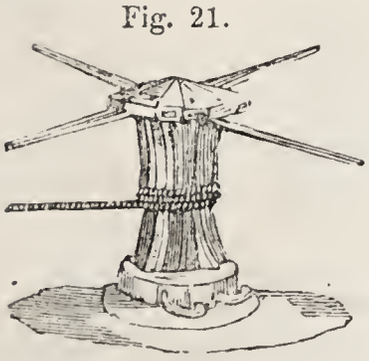
Q. What circumstances LIMIT the utility of the lever?

A. When a lever is applied to raise a weight or overcome a resistance, *the space through which it acts at any one time is small*, and the work must be accomplished by a succession of short and intermitting efforts. The common lever is, therefore, only used in cases where weights are required to be raised through small spaces.

Q. When a CONTINUOUS MOTION is to be produced, as in raising ORE from the MINE, or in weighing the ANCHOR of a ship, what contrivance do we adopt to remove the intermitting action of the lever, and render it continual?

A. That arrangement of the lever generally denominated the *wheel and axle.*

Fig. 21.



Q. What is the form of WHEEL AND AXLE called which is used for lifting the ANCHORS of ships?

A. A *capstan.* (*Fig.* 21.)

Q. Will you describe the construction of a CAPSTAN?

A. It consists of a *vertical spindle* or *shaft* fixed firmly, as in the deck of the vessel, but turning on its axis, and supporting a *solid cylinder* connected with it; the *top of this cylinder* being pierced with holes cut in its periphery, and directed towards its centre. It is then worked by long levers inserted in the holes, by men who walk

in succession round the capstan, and thus make it revolve, while a rope or cable wound about the spindle may act with force sufficient to weigh a ponderous anchor, or warp a heavy-laden vessel into harbour.

Q. In the various forms of WHEELS, how is the POWER applied ?

A. In some cases by a *rope* coiled round the *axle;* in the *common windlass*, by a *winch* or *handle* applied to the axis; and in *water-wheels*, *paddle-wheels*, and *tread-mills*, by a *weight* applied to the *circumference of the wheel.* (*See figs.* 22 and 23.)

Fig. 22.

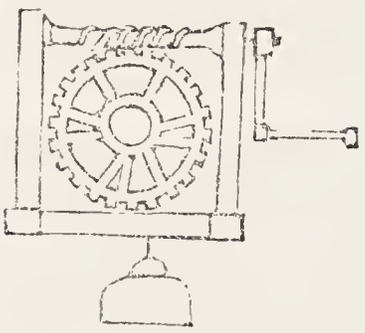


Fig. 23.

Fig. 24.

Q. What is a PULLEY ?

A. A pulley is a *small wheel* turning on *an axis*, with a *rope* passing over it. It is used to change the direction of a weight, which may be raised to any height by a person not moving from his place. (*See fig.* 24.)

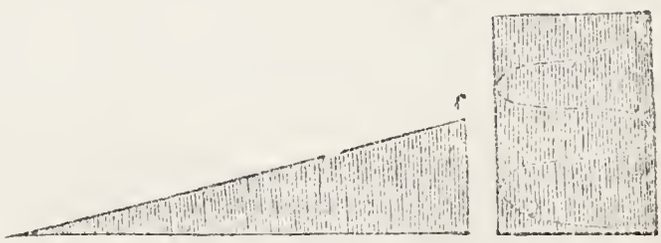
Q. What TECHNICAL NAME is given to pulleys on board ship ?

A. They are called *blocks.*

Q. What is an INCLINED PLANE ?

A. It is a hard plane surface, forming some angle with a horizontal plane; *that angle not being a right angle.* (*See fig.* 25, *a b c.*)

Fig. 25.



Q. What are FAMILIAR EXAMPLES of the INCLINED PLANE ?

A. *Roads* formed on the sides of hills; a *pair of slides*, when in use for assisting in the removal of barrels, &c., from a loaded vehicle to the ground.

Q. Why is it easier to roll a HOGSHEAD into a WAGON up an INCLINED PLANE, than to lift it directly into the WAGON ?

A. The *gravity* or *weight* of a body on an inclined plane may be divided into *two forces; one* drawing it to the earth, acting at right angles to the plane; *the other*, acting parallel to the inclined plane,

and forcing the weight down it. In lifting a body vertically from the earth, we have to overcome the *full force of gravity* acting directly on it; but by rolling it up an inclined plane, we are enabled to move great weights with comparative facility.

Q. Where a ROAD rises ONE foot in TWENTY, how much more labour is imposed on a horse drawing a loaded carriage, than when he draws the same load upon a level?

A. On a level road the carriage moves when the horse exerts power sufficient to overcome the *friction and the resistance of the atmosphere;* but on a road rising one foot in twenty, besides these impediments, the horse is obliged to lift *one-twentieth of the load.*

Q. Why is it bad policy ever to construct a ROAD directly over the SUMMIT of a HILL?

A. Because *half the power*, with the increase of speed, exerted on a *level road round the hill*, would gain the same distance in *half the time.*

It should be remembered that the handle of a bucket is no longer when it lies down than when it stands up.

Q. Do we use INCLINED PLANES in our HOUSES?

A. The *stairs* in our houses are inclined planes in principle; but being so steep, are cut into horizontal and perpendicular surfaces called *steps*, that they may afford a firm footing.

Q. Why does an INTELLIGENT DRIVER, in ascending a steep hill on which there is a broad road, wind from side to side of the road?

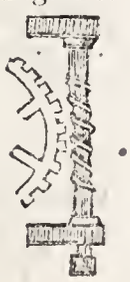
A. By so doing he diminishes the *abruptness* of the ascent, and favours the *strength* of his horses.

Q. What is a SCREW?

A. The *screw* is an *inclined plane winding round a cylinder.* This will be apparent if we take a rectangular piece of paper whose length is equal to the circumference of a glass rod (*see fig.* 25), and wind it round in such a manner that the horizontal side of the paper shall form the periphery *a b* of the base of the cylinder; then the hypotenuse, as the line *a c* is called, will wind around it in a uniformly ascending line, which line marks what is called the thread of the screw.

Q. What is a PERPETUAL SCREW?

Fig. 26.



A. A perpetual screw is the name given where a screw acts on the teeth of a wheel so as to produce a continued rotation of the wheel. (*See fig.* 26.)

Fig. 27.

In practice, the screw is never used as a simple mechanical machine, the power being always applied by means of a lever passing through the head of the screw, or into a nut, which is another screw, through which the first one passes. The screw, therefore, acts with the combined power of the inclined plane and the lever.

Q. What is a WEDGE?

A. A *wedge* (*fig.* 27) is composed of *two inclined planes* united at their bases.

Q. For what purposes is the WEDGE used in the arts?

A. When *enormous force* is to be exerted through a very *small space*, as in the splitting of masses of timber or stone. Ships are raised in docks by wedges driven under their keels.

Q. What are FAMILIAR EXAMPLES of the use of the wedge in ordinary tools or instruments?

A. All cutting and piercing instruments, such as *knives*, *razors*, *scissors*, *nails*, *pins*, *needles*, *awls*, &c., are wedges. The angle of the wedge is more or less acute in these instances, according to the purpose to which it is to be applied.

In tools intended for cutting wood, the angle is generally about 30°; for iron, it is from 50° to 60°; and for brass, from 80° to 90°.

CHAPTER IX.

THE SOURCES OF POWER.

Q. Is there any reason why the term MECHANICAL POWERS should be applied exclusively to the contrivances explained?

A. There is no reason but old usage; since some of the forces which act mechanically with the greatest power are not included in the class of solid bodies, as steam, wind, water.

Q. Why are the SIMPLE MECHANICAL POWERS aids in physical exertion or labour?

A. *Because they allow a small force to take its time to produce any requisite magnitude of effect.* Thus, one man's efforts, or any small power, which is always at command, by working proportionally longer, will answer the purpose of the sudden effort of many men, even of a great number of men, whom it might be impossible to bring together.

Q. Why are so many attempts continually made to produce mechanical engines which shall generate PERPETUAL MOTION?

A. Because the projectors do not understand the great truth, *that no form or combination of machinery can, under any circumstances, increase the quantity of power applied.*

Q. What is the object of a MACHINE?

A. To *receive and distribute motion* derived from an external agent, since no machine is capable of generating motion or moving-power within itself.

Q. What are the PRINCIPAL SOURCES from whence POWER is obtained?

A. *Men* and *animals*, *water*, *wind*, *steam*, and *gunpowder*. The power of all these may be ultimately resolved into those of muscular energy, gravity, heat, and chemical affinity.

Q. Are there any other sources of POWER?

A. Yes; *magnetism*, *electricity*, *capillary attraction*, &c.; but none of these are capable of being used practically for the production of motion.

Q. How is MUSCULAR ENERGY exerted?

A. Through the *contraction of the fibres which constitute animal muscles.* The bones act as levers to facilitate and direct the application of this force, the muscles operating on them through the medium of tendons, or otherwise.

Q. What ANIMALS possess the greatest amount of muscular power?

A. *Beasts of prey.* Some very small creatures, however, possess muscular power in proportion to their bulk incomparably greater than that of the largest and greatest of the brute creation. A *flea*, considered relatively to its size, is far stronger than an *elephant* or a *lion.*

Q. In WHAT METHOD can a man exert the greatest active strength?

A. In *pulling upwards from his feet;* because the strong muscles of the back, as well as those of the upper and lower extremities, are then brought advantageously into action. Hence the action of rowing is one of the most advantageous modes of muscular action.

Q. What is the comparative effect produced in the different methods of applying the FORCE of a MAN?

A. In the action of *turning a crank*, his force may be represented by the number 17; *in working a pump*, by 20; *in pulling downwards*, as in the action of ringing a bell, by 39; and in *pulling upwards from the feet*, as in rowing, by 41.

Q. What is the ESTIMATE of the UNIFORM STRENGTH of an ORDINARY MAN for the performance of daily mechanical labour?

A. That he can raise *a weight of* 10 *pounds to the height of* 10 *feet once in a second*, and continue the labour for 10 *hours in the day.*

Q. In what POSITION will a HORSE, or any OTHER ANIMAL used for labour, exert its power to the best advantage?

A. When the *line of draught is not horizontal*, but *inclines upwards*, making a small angle with the horizontal plane.

Q. What is a "HORSE-POWER?" We say a steam-engine is of a certain horse-power; what is the meaning of the term?

A. The *measure of a "horse's power,"* adopted as a standard for estimating the power of steam-engines, is, *that he can raise a weight of* 33,000 *pounds to the height of one foot in a minute.*

Q. What is the STRENGTH of a HORSE compared with that of MAN?

A. The force of *one horse* is considered to be equal to that of *five men.*

Q. What do we mean by "WATER-POWER?"

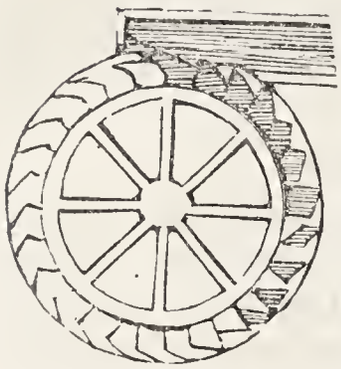
A. The power obtained by the action of water,—applied generally to the circumference of wheels, which it causes to revolve, either *by its weight*, *by its lateral impulse*, or *by both conjointly.*

Q. What are the FOUR FORMS of WATER-WHEELS generally used for moving machinery?

A. The *overshot wheel*, the *undershot wheel*, the *breast wheel*, and the *turbine wheel.*

Q. What is an OVERSHOT WHEEL?

Fig. 28.



A. This is a wheel, the circumference of which is occupied by a series of cavities, commonly called *buckets*, into which the water is delivered by one or more spouts at the top of the wheel, and descends to the bottom. By *fig.* 28, it will be seen that the buckets on one side of the wheel are erect, and will consequently become loaded with water, while those on the other side are inverted, and, of course, empty. It follows that the loaded side will always preponderate, and, by descending, cause the wheel to revolve.

Q. What is an UNDERSHOT WHEEL?

A. One which acts by the *impulse of a current of water* flowing under it, and striking against paddles fastened to the circumference of the wheel. (*See fig.* 29.)

Fig. 29.

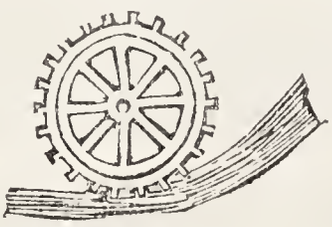
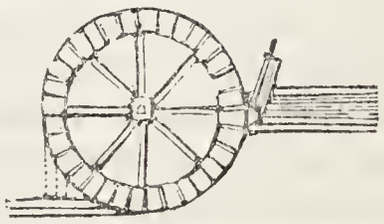


Fig. 30.

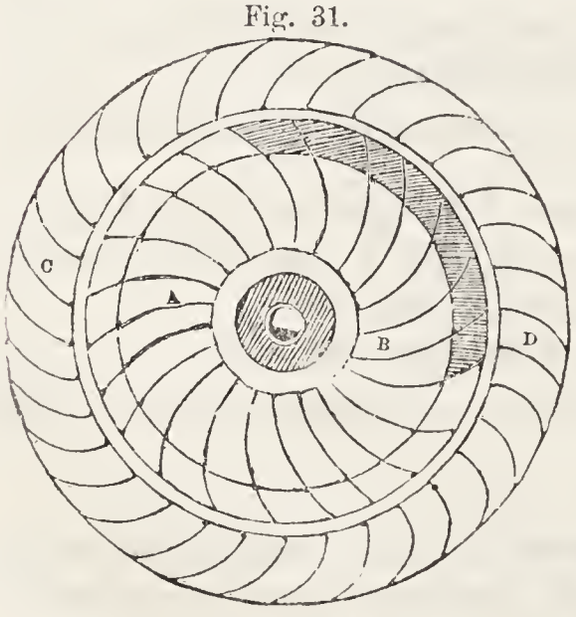


Q. What is a BREAST-WHEEL?

A. One in which the water is *received in buckets* at about half the height of the wheel, as in *fig.* 30

Q. What is a TURBINE WHEEL?

Fig. 31.



A. The turbine wheel (*fig.* 31) consists of a *fixed horizontal wheel*, having *curved channels*, A B, *in the centre of which the water enters; it diverges in every direction, and escapes at the circumference.* Around the fixed wheel is a revolving circle, C D, which, by a series of curves in an opposite direction to those on the fixed wheel, receives the water from the guide-curves of A B, and is driven round by the force of the afflux.

Q. With what VELOCITY will the TURBINE WHEEL be impelled?

A. The velocity will be in proportion to the *pressure of the water*, which, in its turn, is in proportion to the *weight of the vertical column* that is sustained above the opening A B, *fig.* 31.

Q. What is the most economical WATER-WHEEL? or, in other words, what form of water-wheel will accomplish the most work with the least expenditure of water?

A. The *turbine.* In some of the water-wheels, owing to friction and other causes, not one-half the estimated power of the water is obtained or applied to the driving of machinery.

Q. Upon what does the POWER of STEAM depend?

A. Upon the tendency which *water* possesses *to expand into vapour* when *heated* to a certain temperature.

Q. What is GUNPOWDER?

A. A solid explosive substance, composed of *saltpetre* or *nitre*, *sulphur*, and *charcoal*, reduced to powder, and mixed intimately with each other.

Q. Upon what does the POWER of GUNPOWDER depend?

A. When brought in contact with any ignited substance, it explodes with great violence. A vast quantity of *gas, or elastic fluid*, is emitted, the *sudden production* of which, at a *high temperature*, is the cause of the violent effects which this substance produces.

Q. Is the POWER produced in the EXPLOSION of POWDER ever used for PROPELLING MACHINERY regularly?

A. It is not, on account of its *expensiveness* and the *suddenness* and *violence* of its action. It is chiefly applied to the throwing of shot and other projectiles, and the blasting of rocks.

Q. What is the estimated FORCE of GUNPOWDER when exploded?

A. *At least*, 14,750 pounds upon every *square inch* of the surface which confines it.

Q. What are the essential properties of a GUN?

A. To *confine the elastic fluid* generated by the explosion of the powder as completely as possible, and to *direct the course of the ball* in a straight or rectilinear path.

Q. Why will a RIFLE send a BALL more accurately than a MUSKET, or ordinary gun?

A. The *space* produced by the *difference of diameter* between the *ball* and the *bore of the gun* greatly diminishes the effect of the powder, by allowing a part of the elastic fluid to escape before the ball, and also permits the ball to deviate from a straight line. The advantage of a rifle-barrel is chiefly derived from the more accurate contact of the ball with the sides of its cavity.

Q. In what consists the peculiarity and superiority of the "MINIE RIFLE?"

A. In *construction of the ball*, which, in the act of firing, is made to completely fit the barrel or bore of the gun.

Q. How is this accomplished?

A. The shape of the ball is *oblong*, with *a conical point*, and an *opening in its base*, extending up for two-thirds the length of the ball. Into the opening of this internal cylinder there is placed a small *concave section of iron*, which the powder, at the moment of firing, *forces into the leaden ball* with great power, *spreading it open*, and causing it

to fit tightly to the cavity of the barrel in its course out, thus giving it a perfect direction.

Q. On firing a GUN or CANNON, does the piece RECOIL with as MUCH MOMENTUM as the BALL possesses in passing in an OPPOSITE DIRECTION ?

A. It recoils with even *more momentum* than the ball has, for it suffers the reaction *not only of the powder, but also of the ball.*

Q. Why are not the effects of the RECOIL equally evident with the effects of the BALL ?

A. Because the *momentum* in the *gun* is diffused through a *great mass*, and is, therefore, easily checked; while in the ball the momentum is concentrated in a *small compass.*

Q. In some RIFLES the BORE is TWISTED : what is the advantage of this ?

A. It is supposed to produce a *rotation of the ball round an axis*, in the direction of its motion, which renders it less liable to deviate from its path on account of irregularities in the resistance of the air.

Q. To what distance may a BALL be thrown by a TWENTY-FOUR POUNDER ?

A. With a quantity of powder equal to two-thirds the weight of the ball, it may be thrown about four miles.

The effective range of a twenty-four pounder is, however, much less than this.

Q. How much further would the same ball go, were the resistance of the air removed ?

A. About *five times the distance*, or twenty miles.

Q. If a GUN be fired when the MUZZLE is STOPPED with SNOW or CLAY, or PLUNGED beneath WATER, why will it almost certainly burst ?

A. Every force requires *time* to produce its effect; and if the *time requisite* for the elastic vapour (generated by the combustion of the powder) to force out the sides of the barrel *is less* than that in which the *condensation of the air* near the wadding is conveyed in sufficient force to drive the impediment from the muzzle, then the barrel must burst. It sometimes happens that these two forces are so nearly balanced that the barrel only swells, the obstacle giving way before the gun is actually bursted.

Q. Will a GUN recoil more with a charge of FINE SHOT than with a BULLET ?

If a gun is loaded with *ball*, it will *not kick so much* as when loaded with *fine shot ;* and, among different kinds of shot, that which is the smallest causes the greatest recoil against the shoulder.

Q. What is the EXPLANATION of this ?

A. With a ball the velocity is communicated to the whole mass *at once*, but with small shot or sand, the velocity communicated by the explosion *to those particles of the substance immediately in contact with the powder*, is greater than that received *at the same instant* by the *outer particles ;* consequently, a large proportion of explosive force acts momentarily in an opposite direction.

Q. Why is GUNPOWDER always manufactured in LITTLE GRAINS ?

A. In order to cause it to explode *more quickly*, by facilitating the *passage of the flame* among the particles.

Q. Why is RIFLE POWDER manufactured with SMALL GRAINS, and CANNON and BLASTING POWDER of LARGE GRAINS ?

A. Because rifle powder is required to be exploded *more quickly*

and with *greater force.* This end, it is found, can be best attained by the employment of a fine grain. In the form of dust the particles would be too compact.

Q. Are there any more explosive substances than gunpowder?

A. Very many; but all of them are too expensive or dangerous for practical use.

Q. What is the MOST EXPLOSIVE substance known?

A. Chloride of nitrogen. A drop of this substance in an open saucer makes a hole in the bottom of the vessel and the support; because all its particles are decomposed at the same instant.

Q. What is FULMINATING POWDER, or the material used in percussion caps?

A. Fulminate of mercury, or a compound of carbon, nitrogen, oxygen, and oxide of mercury.

Q. What is GUN-COTTON?

A. A product formed by immersing *cleansed cotton* in a mixture of *sulphuric and nitric acids.* By the action of the acids the vegetable fibre becomes changed into an explosive substance, known to chemists under the name of *pyroxyline.*

Q. Why is GUNPOWDER better adapted for explosive purposes than any other compound?

A. Because the *affinities or attractions* existing between the elements composing it *are balanced* in the best manner; not, like some explosive bodies, so loosely interwoven that the slightest mechanical force or the slightest elevation of temperature suffices to cause their explosion, rendering them totally unmanageable and inapplicable either to the purposes of war, mining, or engineering; but having its affinities safely interwoven—securely tranquil—yet ready to spring into action on the application of a definite amount of heat.

Q. Would it be possible to increase the RANGE and the EFFECT of a PROJECTILE fired from a gun or cannon, by using an explosive compound of GREATER POWER than gunpowder?

A. It would not.

Q. For what REASON is it impossible?

A. Supposing that the guns could be made indefinitely strong, and the gunpowder indefinitely powerful, the point would soon be reached where the *resistance which the air opposes* to a body moving very rapidly could balance the *force derived from the explosive compound* which drives the projectile forward. Beyond this point no increase of impulsive force would urge the projectile farther; and this point is considerably within the range of power that can be exercised by common gunpowder.

Q. What OTHER OBJECTION is there to the employment of stronger explosive substances than gunpowder?

A. The *strength of materials* of which guns are made is *limited.*

Q. What is the LARGEST PIECE OF ARTILLERY which can be cast perfect?

A. The largest mortar ever constructed was of iron, twenty-four inches in diameter, and was used by the French at the siege of

Antwerp. The weight of this shell, when empty, was 916 pounds; when loaded, it contained 99 pounds of powder, and was fired by a charge of 30 pounds. For *ordinary* purposes, mortars 13 inches in diameter are used; but for *special* purposes, larger than 13 inches are occasionally employed.

Q. By what TERMS are CANNON of different sizes distinguished?

A. By the *weight of the ball* which they are capable of discharging. Thus, we have 68-pounders, 24-pounders, 18-pounders, and the lighter field-pieces, from 4 to 12-pounders.

Q. What QUANTITY of POWDER is generally used for the discharge of the several pieces?

A. For common brass and iron guns, *one-third the weight of powder to the ball*, whatever the weight of the latter may be.

Q. What is the meaning of the TERM used in GUNNERY, "POINT BLANK?"

A. When the cannon is so pointed that the ball goes *perfectly straight* towards the object aimed at.

Q. What is the meaning of RICOCHET firing?

A. When the ball is discharged in such a manner that it goes *bounding and skipping* along the surface of the ground. In this way a ball can be thrown more effectively, and for a greater distance, than in any other way.

Q. In GENERAL WARFARE, what is the EFFECTIVE DISTANCE at which ARTILLERY can be used?

A. From 500 to 600 *yards*, or from *a quarter to half a mile.* At the battle of Waterloo, the brigades of artillery were stationed about half a mile from each other. Cannon-balls and shells can be thrown with effect to the distance of a mile and a-half to two miles.

Q. What is a SHELL or BOMB?

A. A *hollow globe of iron*, which, being filled with gunpowder and fired from a mortar or howitzer, bursts into pieces during its flight or progress.

Q. In what respect do MORTARS and HOWITZERS differ from ordinary cannon?

A. They are nearly in the shape of a cannon, but are *larger in the bore* or *inside*, and *shorter in length.*

Q. What has been demonstrated by experiment to be the VELOCITY and EFFECT of a SHOT discharged from an 18-POUNDER?

A. It has been found that, by the firing of an 18-pound shot into a butt or target made of beams of oak, when the charges were 6 *pounds of powder*, 3 *pounds*, $2\frac{1}{2}$ *pounds*, and 1 *pound*, the respective depths of the penetration *were* 42 *inches*, 30 *inches*, 28 *inches*, and 15 *inches;* and the velocities at which the balls flew, were 1,600 *feet in a second*, 1,140 *feet*, 1,024 *feet*, and 656 feet.

Q. By whom was GUNPOWDER supposed to have been discovered?

A. It is generally agreed that gunpowder was used by the *Chinese* many centuries before the Christian era. In Europe, its composition and properties were discovered by *Berthold Schwartz*, a Prussian monk, in the twelfth century. It was first used in battle in 1346.

CHAPTER X.

ON THE STRENGTH OF MATERIALS USED IN THE ARTS, AND THEIR APPLICATION FOR ARCHITECTURAL PURPOSES.

SECTION I.—STRENGTH OF MATERIALS.

Q. When MATERIALS are employed for MECHANICAL PURPOSES, upon what does their POWER or STRENGTH, apart from the nature of the material, depend for RESISTING EXTERNAL FORCE?

A. Upon the *shape* of the material, *its bearing*, and the *nature of the force* applied to it.

Q. In what position will a BAR or BEAM sustain the greatest application of force?

A. When it is compressed *in the direction of its length.*

Q. What do we mean by STIFFNESS of a material?

A. It is the resistance to the application of force tending to bend it.

Q. How much STIFFER is a BEAM supported at BOTH ENDS, than one of half the length firmly fixed at only ONE END?

A. Twice as great.

Q. In what FORM can a GIVEN QUANTITY of matter be arranged so as to oppose the greatest resistance to a bending force?

A. In the form of a *hollow tube* or *cylinder.*

Q. Why are the BONES of man and animals HOLLOW and CYLINDRICAL?

A. Because in this form they can with the *least weight* of material sustain the greatest force. In man and animals, the hollow part of the bones is filled with an oily substance called marrow.

Q. Why are the BONES and QUILLS of birds hollow and empty of marrow?

A. In order that they may possess the greatest strength, and by their lightness assist in flying.

Q. Why are the STEMS of SEEDS and GRAIN-BEARING plants HOLLOW TUBES?

A. Because this disposition of matter gives to the stalk its greatest strength, enables it to resist the action of the wind, and sustain, without breaking, the ripened ear of grain or seed.

Q. Is a COLUMN with RIDGES projecting from it, stronger than one that is perfectly smooth?

A. It is.

Q. Why is a HOLLOW TUBE of METAL stronger than the same quantity of metal as a SOLID ROD?

A. Because its substance *standing farther from the centre*, has a greater power of resisting a bending force.

Q. Of two bodies of similar shape, but of different sizes, which is proportionably the weaker?

A. The larger. That a large body may have proportionate strength to a smaller, it must have a greater proportionate amount of material; and beyond a certain limit, no proportions whatever will keep it together; but it will fall in pieces by its own weight.

Q. Why cannot TREES attain an UNLIMITED HEIGHT of TRUNK ?

A. Because, beyond a certain limit, the *weight of the material* will overcome the *supporting strength* of the material.

Q. Why is it impracticable to build SHIPS beyond a CERTAIN SIZE ?

A. Because the *weight of the timber* and other materials contained in them tends to cause them to fall apart.

Q. Why does a PLANK bend and break more readily than a BEAM, and a BEAM resting on its EDGES bear a greater weight than if resting on its SIDE ?

A. Because the resisting lever *is smaller in proportion as the beam is thinner.*

When a single beam cannot be found deep enough to have the strength required in any particular case, as for supporting the roof of a house, several beams are joined together, and in a great variety of ways, as seen in house-rafters, &c., which, although often consisting of three or more pieces, may be considered as one very broad beam, with those parts cut out which do not contribute much to the strength.

Q. Why is a BEAM when bent by its weight in the MIDDLE very liable to break ?

A. Because the *destroying force* acts with the advantage of a *long lever*, reaching from the end of the beam to the centre; and the *resisting force* or strength acts only with the force of a *short lever* from the side to the centre; at the same time, a little only of the substance of the beam on the under side is allowed to resist at all.

This last circumstance is so remarkable, that the scratch of a pin on the under side of a beam, resting as here supposed, will sometimes suffice to begin the fracture.

SECTION II.—APPLICATION OF MATERIALS FOR ARCHITECTURAL OR STRUCTURAL PURPOSES.

Q. What is ARCHITECTURE ?

A. In its general sense it is the *art of erecting* buildings. In modern use, this name is often restricted to the external *forms* or *styles* of building.

Q. To what cause do the DIFFERENT VARIETIES of architecture owe their origin ?

A. To the rude structures which the *climate* or *materials* of any country obliged its early inhabitants to adopt for temporary shelter.

These structures, with all their prominent features, have been afterwards kept up by their refined and opulent posterity. Thus, the Egyptian style of architecture had its origin in the *cavern* or *mound;* the Chinese architecture is modelled from the *tent;* the Grecian is modelled from the *wooden cabin;* and the Gothic from the *bower* of trees.

Q. What are the ESSENTIAL ELEMENTARY PARTS of a BUILDING ?

A. Those which contribute to its *support*, *enclosure*, and *covering.*

Q. What is a PILE ?

A. A *beam of wood pointed at one extremity* and driven forcibly into the earth, to serve as a support or foundation of some structure. It is generally used in marshy or wet places, where a stable foundation could not otherwise be obtained.

Q. Why are LONG COLUMNS supporting GREAT WEIGHTS made SMALLER at the TOP than at the BOTTOM?

A. Because the *lower part of the column* must sustain not only the *weight of the superior part*, but also the *weight which presses equally on the whole column*. Therefore the thickness of the column should gradually decrease from bottom to top.

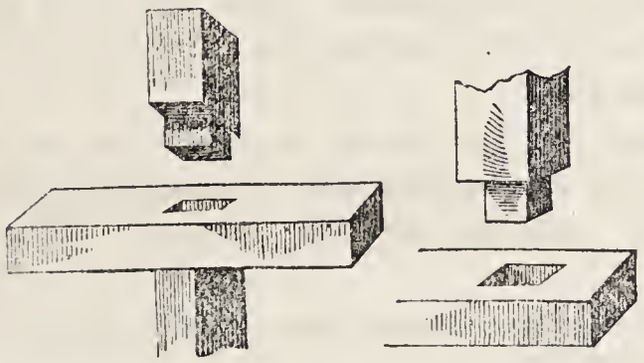
Q. Why are STEEP ROOFS, or those constructed with considerable inclination, best adapted for houses in cold climates?

A. In order that the snow may not be retained upon them, which otherwise would be liable to injure the building by its weight.

Q. In the construction of buildings various terms are employed to designate the method in which the timbers are fitted into each other: what do we mean by MORTISING?

A. Mortising is a *method of insertion* in which the projecting extremity of one timber is received into a perforation in another. (*See fig.* 32.)

Fig. 32.



Q. What is a MORTISE?

A. The *opening* or *hole* cut in one piece of wood to admit the *projecting extremity* of another piece.

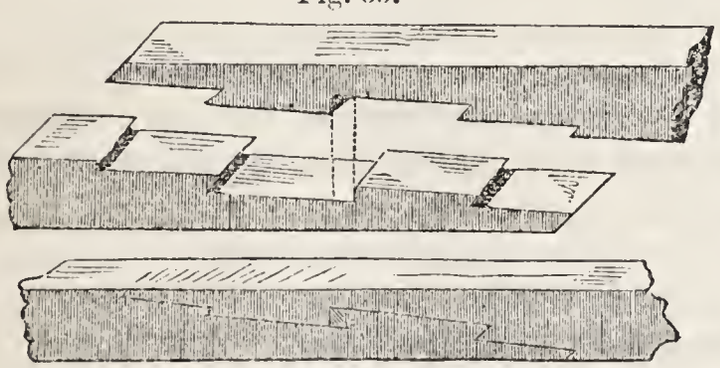
Q. What is a TENON?

A. The *end of a piece of timber* which is reduced in dimensions so as to be fitted into a mortise for fastening two timbers together.

Q. What is SCARFING and INTERLOCKING?

A. It is that method of insertion in which the *ends of pieces overlay each other, and are indented together*, so as to resist longitudinal strain by extension, as in tie bearers and the ends of hoops. (*See fig.* 33.)

Fig. 33.



Q. What is TONGUEING and RABBETING?

A. It is that method of insertion in which the *edges of boards* are wholly or partially received by *channels* in each other.

Q. What is meant by DOVETAILING ?

Fig. 34

A. It is a method of insertion in which the parts are connected *by wedge-shaped indentations*, which permit them to be separated *only in one direction.* (*See fig.* 34.)

Q. What is a CEMENT ?

A. Cements are, for the most part, soft or semi-fluid substances, which have the *property of becoming hard in time*, and *cohering with other bodies to which they have been applied.*

Q. Of what are the ordinary cements which are called MORTARS composed ?

A. Of *quicklime*, *sand*, and *water.*

Q. What is QUICKLIME ?

A. Quicklime is principally *pure lime*, and is obtained from the limestone rock, ordinary marble, or shells, which are composed of carbonate of lime by calcination. The effect of the burning is to drive off the carbonic acid, leaving the lime pure and uncombined.

Q. What is SLACKED LIME ?

A. If quicklime obtained as above described be *wet with water*, it instantly swells and cracks, becomes exceedingly hot, and at length falls into a white, soft, impalpable product. This is denominated "*slacked lime.*"

Q. Why should SLACKED LIME intended for MORTARS be excluded from the air, or used soon after it has been prepared ?

A. Because if exposed to the air it absorbs *carbonic acid*, and becomes converted again into its former condition of *carbonate of lime.*

Q. Why does MORTAR become HARD after a few days ?

A. A portion of the *water* evaporates, and the lime, by a sort of crystallisation, adheres to the particles of sand, and unites them together. The lime also gradually becomes converted into carbonate of lime.

Q. What SAND is most suitable for the formation of MORTAR ?

A. That which is wholly *silicious* and is *sharp ;* that is, not having its particles rounded by attrition.

Q. What are the PROPORTIONS of lime and sand in good mortar ?

A. The proportions are varied in different places: the amount of *sand*, however, always *exceeds* that of the *lime.* The *more sand* that can be incorporated with the lime the better, provided the necessary degree of plasticity is preserved.

Q. What is a WATER, HYDRAULIC, or ROMAN CEMENT ?

A. Those which have the property of *hardening under water*, and of consolidating almost immediately on being mixed.

Q. To what cause do the WATER-CEMENTS owe their property of becoming hard under water ?

A. The cause is not satisfactorily known: all water-cements contain a portion of *burnt clay*, which probably absorbs immediately all

superabundant moisture from the lime, and thus expedites its solidification.

This explanation is rendered the more probable from the fact, that if the clay is burnt sufficient to *vitrify* it or convert it into *brick*, it ceases to form a water-cement.

Q. What are the CONSTITUENTS of a WATER-CEMENT ?

A. *Quicklime*, *sand* or *silica*, and a proportion of *clay*.

Q. What is STUCCO ?

A. *Stucco* is composed of various ingredients, generally of "*plaster of Paris*," sometimes of white marble pulverised and mixed with plaster and lime.

Q. What is TERRA-COTTA ?

A. Literally, *baked clay*, a name given to statues, architectural ornaments, vases, figures, &c., modelled of potters'-clay and fine colourless sand, and afterwards exposed to a most intense heat.

Q. Why are BRICKS when burned usually of a RED COLOUR ?

A. Because the *iron* contained in the clay is converted by the heat into the *red oxide of iron*, and acts in this state as red colouring material.

Q. Why are some BRICKS of a white or yellow colour ?

A. Because the *clay* of which they are formed does not contain *sufficient iron* to colour them.

Q. Why did the CHILDREN OF ISRAEL in making bricks desire to mix STRAW with the CLAY ?

A. The bricks of the Egyptians were composed of clay *simply baked in the sun*, and not burnt. By using straw the clay was held together more firmly, and the brick rendered stronger.

Q. Why are the EGYPTIANS enabled to dispense with the process of burning the bricks ?

A. The extreme dryness of the climate in which they were used enabled them to dispense with the burning. Bricks from Egypt and Babylon, which have remained exposed to the open air uninjured for two thousand years, rapidly fall to pieces when transported to a moist climate.

Q. Why do we mix HAIR with MORTAR ?

A. In order to render it *more cohesive* and *stronger*.

Q. What are TILES ?

A. Plates of burnt clay resembling bricks in composition and manufacture, and used for the coverings of roofs or floors.

Q. What is MASTICH, or MASTIC ?

A. The name given to those cements which contain animal or vegetable substances in composition. Mastich used for the external decoration of houses often contains oil and a preparation of lead.

Q. What is an ARCH ?

A. It is a part of a structure or building suspended over a hollow, and concave towards the area of the hollow.

Q. Is it known at WHAT TIME the ARCH was invented?

A. It is not; it does not appear to have been known to the ancients.

Q. Why is an ARCH capable of resisting a greater amount of pressure than a horizontal or rectangular structure constructed of the same materials?

A. Because the arrangement of the materials composing the arch is such, that the force which would break a horizontal beam or structure is made to *compress all the particles of the arch alike*, and they are, therefore, in no danger of being torn or overcome separately.

Q. What beautiful application of the arch exists in the HUMAN STRUCTURE?

A. In the *skull*, protecting the brain. The materials are here so arranged as to present the greatest strength, with the least weight.

Q. Why is it difficult to break an EGG by pressing directly upon its ends?

A. Because the *shell of the egg* is constructed on the *principle of the arch*, and is therefore capable of resisting great pressure.

Q. Why is a DISHED or ARCHED WHEEL of a carriage much stronger for resisting all kinds of shocks than a FLAT WHEEL?

A. In an arched or dished wheel, the extremity of a spoke cannot be displaced inwards, or towards the carriage, unless the rim of the wheel be *enlarged*, or all the other spokes yield at the same time; and it cannot be displaced outwards, unless the rim be *diminished*, or the other spokes yield in an opposite direction.

Now the rim, being strongly bound with a tire of iron, cannot suffer either increase or diminution, and the strength of all the spokes is thus conferred by it on each individually. In a *flat* wheel, a given degree of displacement, outwards or inwards, of the extremities of a spoke, would less affect the magnitude of the circumference, and therefore the rim of such a wheel secures it much less firmly.

Q. Why are the FORE WHEELS of carriages smaller than the HIND WHEELS?

A. Because they facilitate the turning of the carriage. The advantage of the wheel is proportioned to the magnitude; the smaller wheel having to rise a steeper curve.

Q. What is the ABUTMENT or SPRINGING of an ARCH?

A. The *top of the wall* or walls which receive the *first archstones.*

Q. What is meant by an ORDER in ARCHITECTURE?

A. By an architectural order, we understand a certain mode of *arranging* and *decorating* a *column*, and the adjacent parts of the structure which it supports or adorns.

Q. How many orders are recognised?

A. *Five*:—the *Doric*, *Ionic*, and *Corinthian*, derived from the Greeks; to these the Romans added two others, known as the *Tuscan* and *Composite.*

Q. What are the peculiarities of the DORIC column?

A. The Doric is the *earliest* and *most massive* order of the Greeks. The column is always large, with *a plain cap or capital.* Its height, in the finest examples at Athens, is *six times its diameter;* the true Doric column has twenty flutings, and no base stone. The best

specimens of the Doric order are found in the Parthenon and Temple of Theseus at Athens. (*See fig.* 35.)

Q. What are the peculiarities of the IONIC ORDER ?

A. The Ionic column is a *lighter* order than the Doric, being *eight or nine diameters in height.* It has a base, with twenty-four or more flutings upon the shaft. The capital has two double parallel scrolls, called *volutes*, occupying opposite sides, said to have been copied from ringlets of hair. The best ancient specimens of the Ionic order are to be found in the Temple of Erictheus at Athens. (*See fig.* 36.)

Q. What are the distinguishing peculiarities of the CORINTHIAN ORDER ?

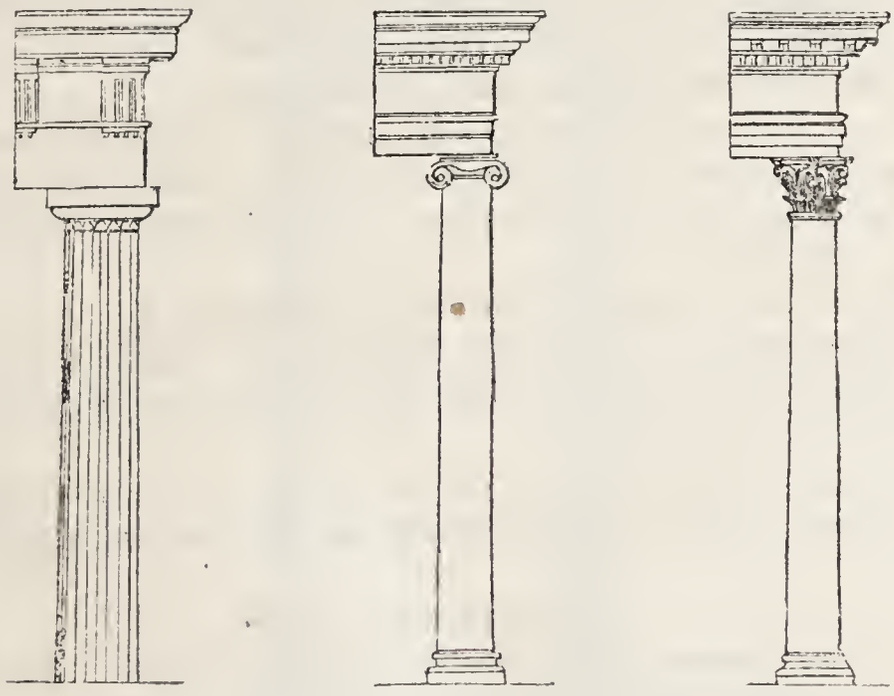
A. The Corinthian was *the highest* and *most decorated* of the Grecian orders. Its base resembled that of the Ionic, but was more complicated. The shaft was often *ten diameters in height*, and was fluted. The capital was shaped like an inverted bell, and covered on the outside with two rows of the leaves of the plant acanthus, above which were eight pairs of small scrolls on volutes. (*See fig.* 37.)

The origin of the Corinthian capital has been ascribed to the sculptor Calimachus, who is said to have copied from a basket accidentally enveloped in leaves of acanthus.

Q. What are the peculiarities of the TUSCAN ORDER ?

A. The Tuscan order, derived from the ancient Etruscans, is not unlike the Doric in many respects. It is not, however, fluted on its shaft, and is supported by a base. There are no vestiges of this order among ancient ruins. (*See fig.* 38.)

Fig. 35. Fig. 36. Fig. 37.



Q. What are the peculiarities of the COMPOSITE ORDER ?

A. This fifth order was made by the Romans out of the *Corinthian*, simply by *combining its capital with that of the Ionic.* Its best example is found in the Arch of Titus at Rome. (*See fig.* 39.)

Fig. 40 represents a modification of the Doric column, called the Roman Doric.

Fig. 38.

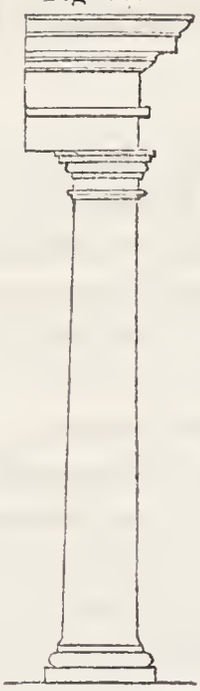


Fig. 39.

Fig. 40.

Q. How do PILASTERS differ from COLUMNS ?

A. Only in their plan, which *is square*, as that of columns is *round:* pilasters are attached to walls.

Q. What is a PORTICO ?

A. A portico is a *continued range of columns* covered at the top to shelter from the weather. The portico of the temple at Palmyra was full four thousand feet long.

Q. What are BALUSTERS ?

A. *Small columns, or pillars of wood, stone, &c.*, used in terraces or tops of buildings for ornament; also to support railing. When continued for some distance, they form a balustrade.

Q. Where did the GOTHIC ORDER of ARCHITECTURE originate ?

A. Among the *northern nations of Europe.* After the destruction of the Roman empire, it was introduced to the exclusion of the Greek and Roman manner of architecture. It seems particularly adapted to religious edifices.

Q. What are the CHARACTERISTICS of the GOTHIC ARCHITECTURE ?

A. *Pointed arches*, with *greater height than breadth* in the proportions, *with profuse ornament*, chiefly derived from an imitation of the leaves and flowers of plants.

Q. What is said to have been the MODEL of the AISLE of A GOTHIC CATHEDRAL ?

A. A *group of tall trees*, meeting at the top with interwoven branches.

Q. What TWO SPECIES of GOTHIC ARCHITECTURE are there ?

A. The *Saxon*, heavy, plain, massive, like the Tuscan; the *Norman*, like the Corinthian architecture, light and ornamental.

Q. Ought ARCHITECTURE to be considered as a FINE or a USEFUL ART ?

A. As a *useful art.*

It is degrading the fine arts to make them entirely subservient to utility. It is out of taste to make a statue of Apollo hold a candle, or a fine painting stand as a fireboard. Our houses are for use, and architecture is therefore one of the useful arts. In building, we should plan the inside first, and then the outside to cover it.

Q. Why is it BAD TASTE to construct a DWELLING-HOUSE in the form of a GRECIAN TEMPLE ?

A. Because a Grecian temple was intended for *external worship*, not as a habitation or place of meeting.

Q. Had the GOTHS, who plundered Rome, anything to do with the invention of GOTHIC ARCHITECTURE ?

A. No; the name was introduced about two hundred years ago as a term of reproach, to stigmatise the edifices of the Middle Ages, which departed from the purity of the antique models.

Q. What is the FAÇADE of a building ?

A. *Its front.*

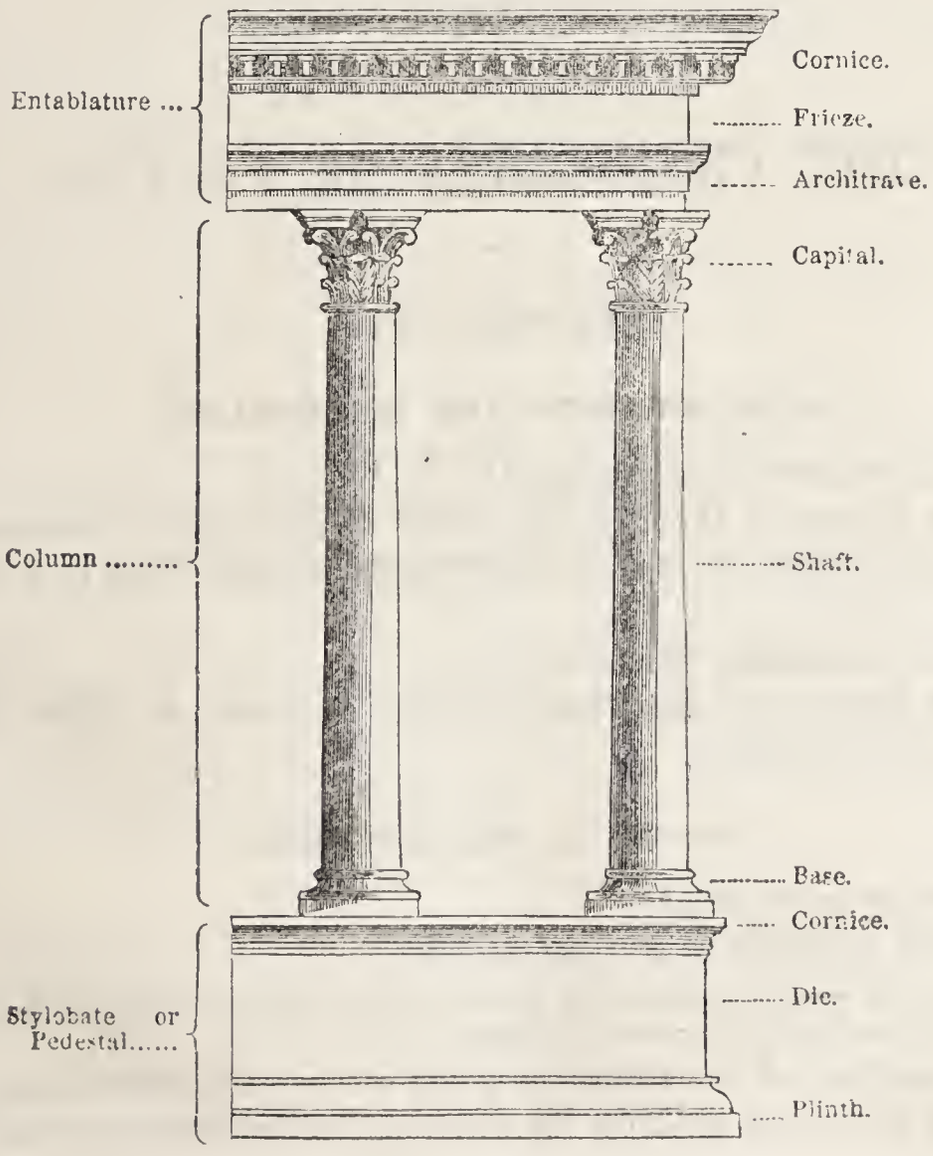
Q. What is a PEDESTAL ?

A. The *lower part* or *base* of the column; a continued base, on which a range of columns is erected, is called a *stylobate.*

Q. What is the PLINTH ?

A. This term is applied to the *lower part of the pedestal*, or to any square projecting basis, such as those at the bottom of walls, and under the base of columns. The lower part of the pedestal being called the plinth, the middle part will be termed the *die*, and the upper part the *cornice of the pedestal.* (*See fig.* 41.)

Fig. 41.



Q. What is the BASE of a COLUMN?

A. The *lower part*, where it is distinct from the shaft.

Q. What is the SHAFT?

A. The *middle* or longest *part* of the column.

Q. What is the CAPITAL?

A. The *upper or ornamental part* resting on the shaft. The height of a column is measured in diameters of the column itself, always taken at the base.

Q. What is the ENTABLATURE?

A. The *horizontal continuous portion* which rests upon the top of a row of columns.

Q. What is the ARCHITRAVE?

A. The *lower part* of the entablature.

Q. What is the FRIEZE?

A. The *middle part* of the entablature.

Q. What is the CORNICE?

A. The *upper or projecting part* of the entablature. (*For illustration of these different terms, see fig.* 41.)

THE PHENOMENA OF FLUIDS.

CHAPTER XI.

HYDROSTATICS AND HYDRAULICS.

Q. What is the SCIENCE of HYDROSTATICS?

A. The science of Hydrostatics treats of the *weight*, *pressure*, and *equilibrium* of water, or other slightly elastic fluids, when in a state of rest.

Q. What is the SCIENCE of HYDRAULICS?

A. The science of Hydraulics treats of *water* or *other slightly elastic fluids in motion.*

SECTION I.—HYDROSTATICS.

Q. Is water an ELASTIC body?

A. Water is elastic in a *slight degree.*

Q. Why does a PIECE of SLATE, when thrown nearly horizontal upon the surface of a lake, as in the game of ducks and drakes, REBOUND?

A. On account of the *elasticity of the water;* the water being compressed by the stone striking its surface, immediately recovers itself

and acts as a spring against the surface of the slate, causing it to rebound.

Q. How does the PRESSURE of a FLUID differ from that of a SOLID ?

A. In solids the pressure is always *downwards*, or *towards the centre of the earth's gravity ;* but in fluids, when confined, *the pressure is exerted in all directions—upwards, downwards, sideways.*

Q. What difference does the SHAPE or SIZE of a vessel make in respect to the pressure of a fluid upon its bottom ?

A. The pressure exercised by a fluid from *above, downwards on the bottom of the vessel* in which it is contained, is quite independent of the form of the vessel, and is always equal to the weight of a column of the fluid, whose base is the bottom of the vessel, and whose height is the vertical distance from the bottom to the surface of the fluid.

Q. Why is the surface of a FLUID at REST always LEVEL ?

A. Because the particles are *equally attracted towards the earth by gravity*, and are all equally and perfectly movable among themselves.

Q. On what PRINCIPLE are we enabled to conduct WATER under GROUND and THROUGH IRREGULAR TUBES ?

A. On the principle that water will always *rise to an exact level in different tubes, pipes,* or *vessels communicating with each other.* Thus, from a lake or reservoir, water can be conveyed in pipes under streets or buildings to any distance, and supplied to any height not exceeding that of its source.

Q. When a SHIP founders in SHALLOW WATER, the wreck, on breaking to pieces, generally comes to the surface, and is cast upon the shore ; but when a SHIP sinks in very DEEP WATER, it never rises : why is this ?

A. The *pressure* of very *deep water* forces the water into the *pores of the wood*, and makes it so heavy that no part of the wreck is enabled to rise again.

Q. Can you sink a CORK so deep that it will not rise to the surface again ?

A. At a *great depth* the water forced by *pressure* into the pores of the cork renders it so heavy that it cannot rise.

Q. In the minds of many persons it is difficult to conceive how water can press UPWARDS as well as DOWNWARDS, and LATERALLY : how can this be rendered evident ?

A. From the fact that, *if in a fluid mass the particles below had not a tendency upwards equal to the weight or downward pressure of fluid over them*, they could not support that fluid which entirely rests upon them. Their tendency upwards is owing to the pressure around them from which they are trying to escape.

SECTION II.—HYDRAULICS.

Q. How slight a DECLIVITY is sufficient to give the RUNNING MOTION to water ?

A. Three inches to a mile in a smooth, straight channel, gives a velocity of about three miles per hour. The river Ganges, at a distance of 1,800 miles from its mouth, is only 800 feet above the level of the sea.

Q. In what WAY can WATER be DISCHARGED most rapidly from a VESSEL?—through a SHORT PROJECTING TUBE in the bottom or side, or through or from a SIMPLE APERTURE of the same dimensions?

A. From the *short tube.*

Q. In what part of a JET or STREAM of flowing water will the greatest velocity be found?

A. At the *point where its dimensions are contracted* to the greatest extent.

Q. In what PART of a RIVER does the water flow MOST RAPIDLY?

A. In the *middle of the stream, at the surface.* On the sides and bottom the velocity is diminished by the friction of the water against the banks, bars, &c.

Q. Why will a PIPE TWO INCHES in diameter give more water than FIVE PIPES in the same position, of one inch in diameter?

A. Because the water flows with much *greater velocity* in the large pipe than in the small ones, there being much *less friction* in the former than in the latter.

CHAPTER XII.

PNEUMATICS.

SECTION I.—GENERAL PROPERTIES OF AERIFORM BODIES.

Q. What is the object of the science of PNEUMATICS?

A. To explain and illustrate those phenomena which arise from the *weight, pressure,* or *motion* of *common air,* or other fluids possessing the same general properties.

Q. On what rests the distinction between LIQUIDS and GASEOUS BODIES?

A. The distinction between liquids and those more elastic fluids which we term air, gas, vapour, steam, &c., depends principally *on heat and pressure.* Thus, water, according to the addition or subtraction of heat, may exist as a solid—ice; as a liquid—water; or as a vapour—steam.

Q. Under what pressure of the atmosphere is water converted into STEAM?

A. Under the ordinary pressure of the atmosphere, water is converted into steam at 212 degrees, Fahrenheit's thermometer; if this pressure is increased, it requires a proportionably higher temperature; if this pressure is diminished, the amount of heat required is proportionably less.

Q. How many kinds of AERIFORM or GASEOUS BODIES exist in nature?

A. Those which, under *common circumstances of temperature and pressure,* are always in a gaseous state, as common air; and those which become gases *chiefly at high temperature,* as steam, or vapour of water.

Q. What is ATMOSPHERIC AIR ?

A. A *transparent fluid*, composed mainly of two gases, *oxygen* and *nitrogen*, the ultimate particles of which appear to be destitute of cohesion; hence air has a disposition not only to sink down and spread out laterally, like liquids when unconfined, but also to expand and rise upwards.

Q. Is the AIR POROUS ?

A. Yes; in a *very high degree.*

Q. How do we know this FACT ?

A. Because air readily yields to pressure, and a great bulk of it may be forced to occupy a very small space.

Q. Is air also IMPENETRABLE ?

A. Yes; *beyond a certain limit* it cannot be compressed.

Q. How much LIGHTER is STEAM than ordinary AIR ?

A. Steam has but little more than *half the weight of atmospheric air;* and hence it rises and floats in the air as a cork rises and floats in water.

SECTION II.—ATMOSPHERIC AIR.

Q. What do we understand by the ATMOSPHERE ?

A. The thin transparent fluid which surrounds the earth to a considerable height above its surface, and which, by its peculiar constitution, supports animal life by respiration, and is also necessary for the due exercise of the vegetable functions.

Q. Is the ATMOSPHERE INVISIBLE ?

A. It is generally, but erroneously, so regarded. *The atmosphere is not invisible.*

Q. How can you prove that the ATMOSPHERE is not INVISIBLE ?

A. Because when we look upwards into the firmament on a clear day, the vault appears of *an azure or clear colour.*

This colour belongs not to anything which occupies the space in which the stars or other celestial objects are placed, but to the mass of air through which the bodies are seen.

Q. If the air be an AZURE-COLOURED body, why is not that portion which immediately surrounds us perceived to have this colour, in the same manner that a blue liquid contained in a bottle exhibits its proper hue ?

A. There are certain bodies which reflect colour so faintly, that when they exist in limited quantities, the portion of coloured light they reflect to the eye is insufficient to produce sensation; that is, to excite in the mind a perception of the colour. Almost all semi-transparent bodies are examples of this.

If a glass tube of small bore be filled with sherry wine, or wine of a similar colour, and looked at through the tube, it will be found to have all the appearance of water, and be colourless. If viewed from above, downwards in the direction of its length, it will be found to possess its original colour. In the first instance there can be no doubt but that the wine has the same colour as the liquid of which it originally formed a part; but existing only in small quantity, that colour is transmitted to the eye so faintly as to be insufficient in producing perception.

Q. Why do DISTANT MOUNTAINS appear BLUE ?

A. Not because it is their colour, but because it is *the colour of the air through which they are seen.*

Q. Why does the OCEAN appear GREEN, and a GLASS of the same WATER appear colourless ?

A. Because in the small mass of water the *amount of colour is too small* to be perceptible, while in the entire quantity it is sufficient.

Q. Has AIR WEIGHT ?

A. *It has ;* as well as lead, stone, or any other material substance.

Q. How can this be readily proved ?

A. By weighing a vessel filled with air, and the same vessel after the air has been exhausted from it.

Q. Can the existence of air be known by the SENSE of TOUCH OR FEELING ?

A. It can ; since *it opposes resistance when acted upon*, and strikes with a force proportionate to the speed of its motion.

Q. Why do we always feel a BREEZE on the DECK of a STEAMBOAT in motion, even upon the calmest day ?

A. Because our bodies *forcibly displace the air as we are carried through it.*

Q. What is WIND ?

A. Simply *air in motion*

Q. How are the WAVES of the OCEAN produced ?

A. By the *force of the air in motion*, or wind striking upon the surface of the water.

Q. Why are WAVES calmed and subdued by pouring OIL upon the surface of the water ?

A. The oil, from its inferior specific gravity, *forms a floating film*, which defends the surface of the water from contact with the currents of air ; and the friction between the wind and the waves is greatly diminished, in the same manner that the friction between solids is by the application of unctuous matter.

Q. Could a BIRD fly in a SPACE DEVOID of AIR, even if it could exist without respiration ?

A. It could *not ;* as the bird rises simply by the *resistance* of the particles of air to the beating of its wings.

Q. How do we know that AIR IS ELASTIC ?

A. Because a volume of compressed air, the pressure being removed, immediately restores itself to its original bulk.

Q. When is AIR said to be RAREFIED ?

A. When a given quantity of air is caused to expand and occupy a greater space, it is said to be *rarefied.*

When a part of the air enclosed in any vessel is withdrawn, that which remains, expanding by its elastic property, always fills the dimensions of the vessel as completely as before. If nine-tenths were withdrawn, the remaining one-tenth would occupy the same space that the whole did formerly.

Q. What is the HEIGHT of the ATMOSPHERE above the SURFACE of the EARTH ?

A. It is supposed to be about 45 *miles ;* the zone or shell of air

which surrounds the earth to the height of nearly $2\frac{3}{4}$ miles from its surface, contains one-half of the atmosphere; and the remaining half, being relieved of this superincumbent pressure, expands into another zone or belt of the thickness of 41 or 42 miles.

Some authorities suppose this last zone to have a much greater area.

Q. What is the WEIGHT of AIR compared with that of WATER?

A. Water is about 840 *times* the weight of air, taken *bulk for bulk.*

Q. What is the ESTIMATED WEIGHT of the WHOLE ATMOSPHERE enveloping the globe?

A. To the weight of a *globe of lead sixty miles in diameter.*

Q. As air has weight, and as the mass of it extends at least 45 miles above the earth's surface, WHAT AMOUNT of PRESSURE does it exert?

A. At the *level of the ocean* the atmosphere exerts a pressure of about 15 *pounds for every square inch of surface.*

Q. If the AIR were condensed so as to occupy no more space than the same WEIGHT of WATER, to how great an elevation above the earth would it extend?

A. To an elevation of *thirty-four feet.*

Q. In what DIRECTION is the PRESSURE of the ATMOSPHERE exerted?

A. It is the nature of a fluid to transmit pressure in *every direction equally;* therefore the air presses *upwards*, *downwards*, *laterally*, and *obliquely*, with the same force.

Q. How great a pressure is exerted by the air upon the body of a MAN or ANIMAL having a surface of 2,000 square inches?

A. Not less than 30,000 *pounds*, or *about* 15 *tons.*

Q. Why is not the INDIVIDUAL CRUSHED beneath so enormous a load?

A. Because the atmosphere *presses equally in all directions*, and *our bodies are filled with liquids* capable of sustaining pressure, or with *air of the same density* as the external air; so that the *external pressure* is met and counteracted by the *internal resistance.*

Q. How can this be illustrated EXPERIMENTALLY?

A. If we take a glass cylinder open at both ends, and over one end tie a piece of bladder, *no pressure is perceived*, because the air within the cylinder presses upon or exerts a supporting power equal to the weight resting upon it; but, if by an air-pump we *remove* the air under the bladder, the bladder will immediately exhibit the effects of the pressure, and eventually be *torn asunder* in consequence.

Q. Why are not the ANIMALS living at great DEPTHS in the OCEAN, and subjected to a pressure SIXTY or NINETY times GREATER than we sustain at the bottom of our ocean of air, CRUSHED, or at LEAST IMPEDED, in their motions?

A. Because the pressure of the water is *equal on all sides*, and the bodies of these animals are equally pressed *above*, *below*, and *around*, and the *fluids within* the animal are also of similar density.

Q. What happens when FISHES living at great depths of the sea are drawn to the surface?

A. They are *almost instantly destroyed*, by the expansion of the fluids within them on the removal of the pressure of the water.

Q. What would be the effect upon a MAN or ANIMAL, if AT ONCE RELIEVED of all atmospheric pressure?

A. All the *blood* and *fluids* of the body would be *forced by expansion to the surface*, and the animal would burst.

Q. In what does the surgical operation of CUPPING consist?

A. In removing the atmospheric pressure from the part of the body submitted to the operation.

Q. How is this effected?

A. A vessel with an open mouth is connected with a pump or apparatus for exhausting the air. The mouth of the vessel is applied in air-tight contact with the skin; and by working the pump a part of the air is withdrawn from the vessel, and consequently the skin within the vessel is relieved from its pressure. All other parts of the body being still subjected to the atmospheric pressure, and the elastic force of the fluids contained in the body having an equal degree of tension, that part of the skin which is thus relieved from the pressure will be swollen out, and will have the appearance of being sucked into the cupping-glass. If the skin be punctured with lancets, the blood will be drawn or forced out.

Q. What do we mean by a VACUUM?

A. *A space devoid of all matter;* in general, we mean by a vacuum, a space devoid of air.

Q. Can a PERFECT VACUUM be produced ARTIFICIALLY?

A. *No;* but confined spaces may be deprived of air sufficiently for all experimental or practical purposes.

Q. Are there any instances of a VACUUM in NATURE?

A. There is no reason for supposing the interplanetary spaces to be filled with any material substance.

Q. What do we mean by the DENSITY of the AIR?

A. By the density of air we mean the *quantity contained in a given bulk.* Thus, when one portion contains twice as many particles of air in a given space as another, the first portion is said to possess twice the density of the second.

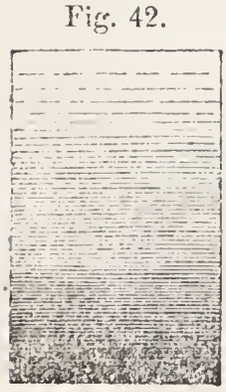
Q. Is there any LAW regulating the DENSITY of the ATMOSPHERE?

A. The *density of the air decreases with the altitude.*

Q. To what is this owing?

A. To the *diminished pressure of the air*, and the *decreasing force of gravity.* Those portions directly incumbent upon the earth are most dense, because they bear the weight of the superincumbent portions; thus, the hay at the lower part of the stack bears the weight of that above, and is therefore more compact and dense.

Fig. 42.



In the accompanying engraving this idea may be conveyed by the gradual shading, which denotes the gradual diminution in the density of the atmosphere in proportion to its altitude.

Q. Why do persons who ascend in BALLOONS feel intense pain in their eyes and ears?

A. Because the air of the upper regions is *more rarefied* than that on the earth; and the air inside their bodies (seeking to become of the same rarity) *bursts through their eyes and ears*, producing intense pain.

Q. Why is it often PAINFUL and difficult to BREATHE on a MOUNTAIN-TOP?

A. Because, owing to the *extreme rarity* of the air on the top of the mountain, a person, although expanding his chest as much as usual, really takes in only half as much air as he does when at the foot of the mountain.

Q. What effects are produced by the RAREFACTION of AIR at LOFTY elevations, as on the tops of high mountains?

A. The *intensity* of sound is *lessened*, respiration is impeded, and the minute veins of the body swell and open. Travellers, in ascending the high mountains of South America, have noticed the blood to gush from the pores of the body, and the skin in many places to crack and burst.

Q. Why do persons WHO DESCEND IN DIVING-BELLS FEEL PAIN in their eyes, and other sensitive parts of their bodies?

A. Because the pressure of the water upwards *compresses* the air in the diving-bell.

Q. Why do we feel OPPRESSED just PREVIOUS to a storm?

A. Because the air is greatly *rarefied by heat and vapour;* and the air inside us (seeking to become of the same rarity) produces an oppressive and suffocating feeling.

Q. Is the EXISTENCE of AIR necessary to the production of SOUND?

A. *It is;* in a *vacuum* there can be *no sound;* and on the top of high mountains, where the air is greatly rarefied, as on Mont Blanc, the report of a pistol can hardly be heard.

Q. Can you BOIL an EGG on the top of a very high mountain?

A. Travellers have found it *impossible*, since the temperature at which water boils is *dependent on the pressure of the air;* and in places where the pressure is very slight, the water boils and is converted into steam without becoming sufficiently hot to cook the egg.

On the top of Mount St. Bernard, 7,688 feet above the sea-level, water boils at a temperature of 209° F.

Q. If the LIPS be applied to the BACK of the HAND, and the breath drawn in so as to produce a PARTIAL VACUUM in the MOUTH, why will the SKIN be drawn or sucked in?

A. Not from any force resident in the lips or the mouth drawing the skin in, but from the fact that the usual external pressure of air is removed, and that the *pressure from within the skin* is suffered to prevail.

Q. How is a BOY enabled to LIFT a STONE by means of the COMMON SUCKER?

A. The sucker consists of a *disc of moistened leather*, with a string by which it may be suspended with any weight attached to it. If its smooth, moist surface be pressed so closely against the flat side of a stone or other body that the air cannot enter between them, the

weight of the atmosphere pressing upon the upper surface of the leather makes it adhere so strongly, that a stone of weight proportioned to the extent of the disc of leather may be raised by lifting the string.

Q. How great a WEIGHT can be raised by the SUCKER?

A. The effect of the sucker arises from the exclusion of the air between the leather and the surface of the stone, &c. The weight of the atmosphere presses their surfaces together with a force amounting to 15 pounds on every square inch of those surfaces in contact. If the sucker could act with full effect, *a disc an inch square would support a weight of* 15 *pounds; two square inches*, 30 pounds, &c.; the practical effect, however, of the sucker is much less.

Q. Why do smooth plates of polished GLASS, MARBLE, or METAL stick together?

A. Because their surfaces are brought into such close contact that the *air cannot insinuate itself between them;* therefore the outside pressure of the atmosphere holds them together with a force corresponding to the extent of the surface of contact.

Q. How are FLIES, and other SMALL INSECTS, enabled to WALK ON CEILINGS and surfaces presented downwards, or upon smooth panes of glass in an upright position?

A. Their feet are formed in such a manner that they *act as small air-pumps or suckers*, excluding the air between them and the surface with which they are in contact; and the atmospheric pressure keeps the animal in position.

Q. How are SNAILS, LIMPETS, and other like animals enabled to ADHERE to the ROCKS?

A. The surface of their shells at the openings are capable of being exactly fitted to any plane surface; these animals have the power of producing a vacuum within their shells when thus fixed, and the atmosphere consequently presses upon them and holds them in their places.

Q. What causes some PEARL-DIVERS to be DEAF?

A. Because the membrane of the tympanum is *ruptured* by the *pressure of the water.* The deafness thus produced is, in many cases, incurable.

Q. Why do the SAILS of a windmill turn round?

A. Because the wind, blowing against the oblique surface of the sails, pushes them out of the way, driving them from place to place in a restless round.

Q. Why in BREATHING do we first DRAW in the BREATH, as it is termed?

A. Because by so doing we make *an enlarged space in the chest*, and the *pressure of the external atmosphere* forces the air in to fill it.

The air enters the lungs, not because they draw it in, but by the weight of the atmosphere forcing it into an empty space.

Q. How is the AIR caused to ESCAPE from the lungs?

A. Simply by means of its *elasticity;* the lungs by muscular action compress the air contained in them, and give to it by compression a greater elasticity than the air without. By the excess of the elasticity it is propelled, and escapes by the mouth and nose.

Q. Upon what does the ACTION and USE of the COMMON BELLOWS depend?

A. Upon the *elasticity and compressibility* of the air.

In the lower board of the bellows is a hole covered by a valve, consisting of a flat piece of stiff leather, movable on a hinge, and which lies on the opening, but is capable of being raised by a slight pressure. When the upper board of the bellows is raised, the internal cavity is suddenly enlarged, and the air contained in it is considerably rarefied. The pressure of the atmosphere forces in air at the nozzle, but this being too small to allow its admission with sufficient ease and speed, the valve covering the hole is acted upon by the atmosphere and raised, and air rushes in through the large aperture under it. When the space between the boards is filled with air in its common state, the upper board is depressed, and the air confined in the bellows is suddenly condensed. The valve covering the hole is thus kept firmly closed, and the air has no escape except through the nozzle, from which it issues with a force proportioned to the pressure exerted on the upper board.

Q. Why will not LIQUOR flow CONTINUOUSLY from a CASK after it has been tapped or pierced, unless another OPENING is made as a VENT-HOLE in the UPPER PART of the CASK?

A. Because the *force of the air pressing upon the mouth of the opening*, having nothing to counterbalance it, would support a column of liquor, if the cask was air-tight, the height of which would be proportioned to the weight of the column of liquor.

Q. What is the effect when the air acts through the VENT-HOLE?

A. When the air is enabled to act through the vent-hole above, the pressure below is counterbalanced, and the liquor descends and runs through the opening by the effect of its own weight.

Q. What is the EFFECT if the lid of a tea-pot be air-tight?

A. If the lid of the tea-pot be *air-tight*, the liquid will flow *freely* for a short time, and then *cease*.

Q. Explain this.

A. By the *escape* of some portion of the liquid, the air under the lid *expands* in the enlarged space and becomes *rarefied;* the pressure on the surface of the liquid in the vessel is then so far *diminished*, that the atmospheric pressure on the outside *resists* its discharge at the spout.

Q. How is this REMEDIED?

A. By the *hole* in the lid, which allows the air to enter *from without.*

Q. Upon what principle does the construction of GAS-HOLDERS or TANKS and GASOMETERS depend?

A. *Upon the pressure of the atmosphere.*

Q. Suppose a vessel having its mouth upwards be completely filled with a liquid, the mouth then to be stopped by pressing a smooth plate of glass or metal against it, and the vessel to be INVERTED; the mouth being plunged into a cistern filled with the same liquid, would the liquid FLOW OUT of the inverted vessel?

A. If the height of the vessel in this case be *less* than the height of the *column* of the liquid which the atmospheric pressure would support, the vessel will continue to be *filled* even after the plate is removed from its mouth.

Q. Can you explain why the water will NOT FALL OUT of the inverted vessel after the plate is removed?

A. The *atmospheric pressure* acting upon the surface of the liquid

in the cistern, will prevent the liquid contained in the vessel from falling out.

Q. What would be the EFFECT if air were introduced by means of a tube through the water, and suffered to escape just UNDER the MOUTH of the inverted vessel?

A. If air were introduced by means of a tube, and suffered to escape immediately under the mouth of the inverted vessel, it would *ascend in bubbles*, find its way to the highest part of the vessel, and *expel the water* from it.

Q. How MUCH water can be expelled in this way?

A. The water will continue to be expelled as long as *air is supplied*, until *all the water* contained in the vessel is expelled, and the vessel is *filled with air.*

Q. Suppose the process to be CONTINUED, what would be the effect?

A. If the process be continued, the air will begin to *escape under the edge of the vessel*, and rise in bubbles to the surface. (*See fig.* 43.)

Fig. 43.

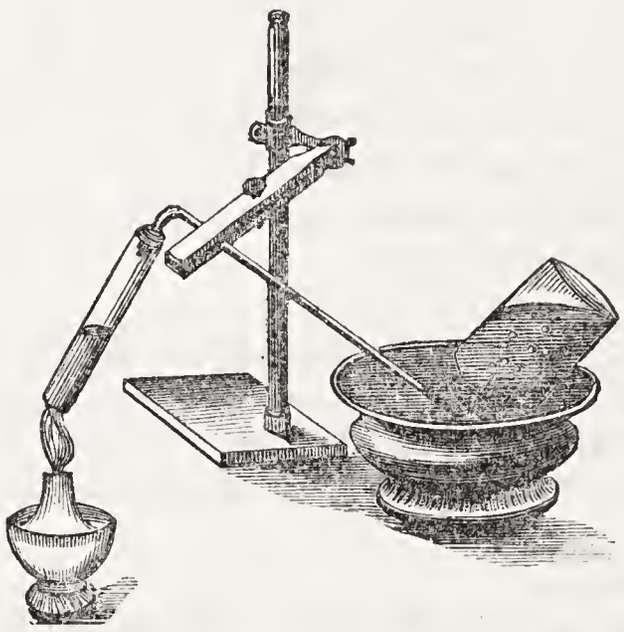
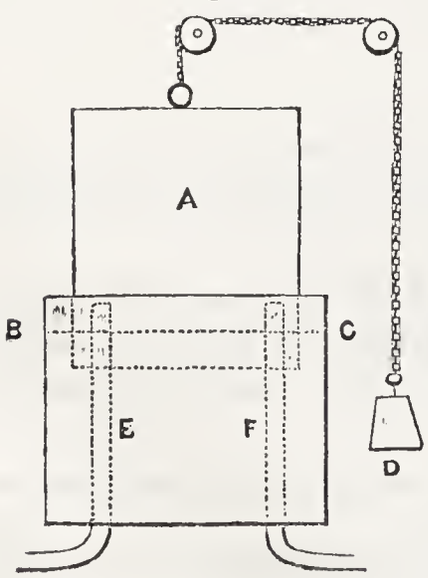


Fig. 44.



Large gasometers, such as are necessary for the illumination of towns, are also constructed on the above principle. They consist of a large inverted vessel, A (fig. 44), made of iron, of a cylindrical form, and suspended over a reservoir of water B C, of a little larger size, by means of counterweights D. The gas is introduced by pipes, ascending from the bottom of the reservoir E and F, and rising a little above the surface of the water. While the gasometer is filling with gas, t gradually rises out of the water until it is filled, after which no more gas is admitted, and its contents are ready to be distributed through the pipes by which it is intended to be conveyed to the place to be illuminated by burning it. As the gas is forced out by the weight of the gasometer and is burned, the gasometer gradually descends into the water till the whole of its contents are expelled, when it is again filled by the same process as before.

Q. Why does a BOTTLE or JUG GURGLE when LIQUID is freely poured from it?

A. On account of the *pressure of the atmosphere forcing air* into the interior of the bottle. In the first instance, the neck of the bottle is filled with liquid, so as to stop the admission of air. When a part has flowed out, and an empty space is formed within the bottle, the atmospheric pressure forces in a bubble of air through the liquid in the neck, which, by rushing suddenly into the interior of the bottle, produces the sound.

Q. When will a BOTTLE CEASE to GURGLE?

A. *So long as the neck continues to be choked with liquid, the gurgling sound continues;* but as the contents of the bottle are discharged, the liquid, in flowing out, only partially fills the neck; and, while a stream passes out through the lower half of the neck, a stream of air passes in through the upper part. The flow being now continued and uninterrupted, no gurgling sound takes place.

Q. Does AIR EXIST in WATER?

A. Water, and most liquids exposed to the air, *absorb a greater or less quantity*, which is maintained in them by the pressure of the atmosphere acting on the surface.

Q. Why is BOILED WATER FLAT and INSIPID?

A. Because the *agency of the heat expels the air* which the water previously contained.

Q. Could FISHES and other MARINE ANIMALS LIVE in water DEPRIVED of AIR?

A. *They could not*, as they breathe the air contained in the water.

Q. Why do ALE, PORTER, and CIDER FROTH, and CHAMPAGNE SPARKLE, when uncorked and poured into an open vessel?

A. When these liquors are bottled, the *air* confined under the cork *is condensed*, and exerts upon the surface a *pressure greater* than that of the atmosphere. This has the effect of holding, in combination with the liquor, air or gas which, under the atmospheric pressure only, would escape. If any air or gas rise from the liquor after being bottled, it causes a still greater condensation, and an increased pressure above its surface. When the cork is drawn from a bottle containing liquor of this kind, the air fixed in the liquid, being released from the pressure of the air which was condensed under the cork, instantly makes its escape, and, rising in bubbles, produces effervescence and froth.

Q. Why do BOTTLES containing ALE, CIDER, PORTER, &c., frequently BURST?

A. It is the nature of these liquids to produce *gas or air* in considerable quantities, *the elastic force of which* sometimes becomes greater than the cohesive strength of the particles of matter composing the bottle, which then necessarily gives way, or bursts.

Q. Why does ONE KIND of LIQUOR FROTH, and ANOTHER KIND only SPARKLE?

A. Those liquors only which are *viscid, glutinous, or thick, froth*, because they retain the little bubbles of air as they rise; while a thin liquor, like champagne, suffers the bubbles to escape readily.

Q. What is the reason that CHAMPAGNE and other aerated liquors are so COOL when first decanted?

A. Because the gas or air contained in them, in assuming its gaseous form, *absorbs a large quantity of heat*, and renders it latent or imperceptible.

SECTION III.—THE PUMP AND BAROMETER.

Q. Why, when we SUCK up a LIQUID with a TUBE or STRAW, does the LIQUID rise to the MOUTH?

A. One end of the tube being placed between the lips, the air is removed from the tube by the ordinary process of inhaling, when the *pressure of the atmosphere* compels the liquid to fill the space deserted by the air.

Q. Through how GREAT a LENGTH of TUBE could we RAISE a LIQUID by SUCTION?

A. About *thirty-two feet.*

Q. Why can we not raise it ABOVE THIRTY-TWO FEET?

A. Because the *atmospheric pressure* will only support or balance a column of water or similar liquid of that height.

Q. How did the PHILOSOPHERS of the sixteenth century ACCOUNT for the fact that water would rise in a tube when the air was sucked out of it?

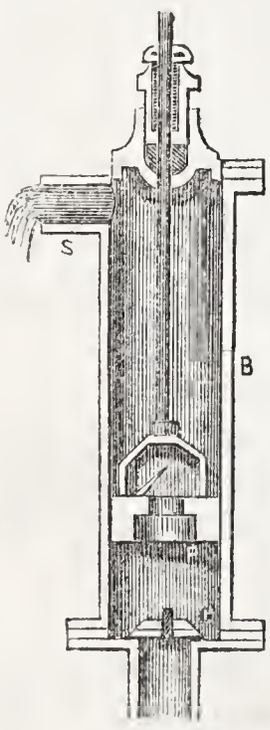
A. They declared that *Nature abhorred a vacuum*, and that she therefore compelled the water to fill the space deserted by the air.

Q. What REASON is said to have been given in explanation of the fact that water could not be raised by suction above thirty-two feet?

A. It was said that Nature's abhorrence of a vacuum extended only to the height of *thirty-two feet*, but that beyond this her disinclination to use empty space did not extend.

Q. How is the common pump CONSTRUCTED?

Fig. 45.



A. The common pump consists of a *hollow tube*, the *lower part* of which, descending into the water, is called the *suction-pipe*, and the *upper part*, *b*, *fig.* 45, the *barrel* or *cylinder;* of a *spout*, *s*, at the top of the cylinder; of an *air-tight piston*, which works up and down in the cylinder; and of two valves, both opening upwards, one of which, *g*, is placed at the top of the suction-pipe, and the other, *p*, in the piston.

Q. How does the common pump OPERATE?

A. When the piston is raised from the bottom of the cylinder, the air above it is *drawn up*, leaving a *vacuum* below the piston; the water in the well then rushes up through *the valve*, *g*, and fills the *cylinder;* the piston is then forced down, shutting the valve, *g*, and causing the water to rise through the piston-valve, *p;* the piston is then raised, closing its valve, and raising the water above it, which flows out of the spout, *s*.

Q. How HIGH can WATER be RAISED by the COMMON SUCTION-PUMP?

A. As the action of this pump depends upon the pressure of the atmosphere, water cannot be raised by it from a depth of *more than* 34 *feet below the upper valve*, and in practice a much shorter limit is usually assigned.

Q. A TINMAN of SEVILLE, in SPAIN, ignorant of the principles of science, undertook to construct a suction-pump to raise water from a well sixty feet deep; when the machine was finished, he was confounded at discovering that it had no power to raise water at all, and enraged at his disappointment, while some one was working the pump, he struck the suction-pipe with a hammer, or axe, so forcibly as to crack it, when, to his surprise and delight, the water almost immediately began to flow, and he found he had attained his purpose. How is this result to be ACCOUNTED for?

A. The explanation is as follows: *the air pressed in through the slit, or aperture of the suction-pipe*, and becoming mixed with the water in its ascent, *formed a compound fluid* far lighter than water alone, and therefore acted upon more readily by the atmospheric pressure; and thus produced the phenomenon described.

Q. How HIGH can WATER be raised in the SUCTION-PUMP by resorting to the expedient above described?

A. About *fifty-five feet*, instead of thirty to thirty-four.

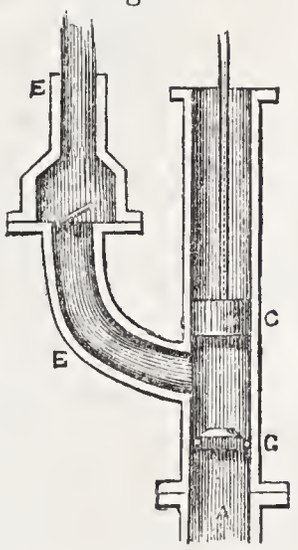
Q. To whom is the INVENTION of the COMMON PUMP attributed?

A. To *Ctesibius*, an Athenian engineer, who lived at Alexandria, in Egypt, about the middle of the second century before the Christian era.

Q. When it is desired to raise water ABOVE thirty-four feet, as in FIRE-ENGINES, &c., how is it accomplished?

A. By means of the *forcing-pump*.

Fig. 46.



Q. In what manner is the FORCING-PUMP constructed?

A. In the forcing-pump atmospheric pressure plays but a small part. There is no valve in the piston, *c* (*fig.* 46), but the water raised through the suction-pipe *a*, and the valve *g*, is forced by each depression of the piston up through the pipe *e e*, which is furnished with a valve to prevent the return of the fluid.

Q. Who first ascertained and demonstrated the REASON for the ASCENT of WATER in a TUBE by SUCTION, and in the COMMON PUMP?

A. *Torricelli*, a pupil of Galileo.

Q. How was he led to his conclusions?

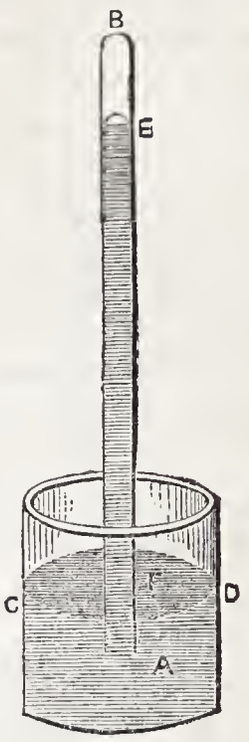
A. He argued, that whatever be the cause which sustained a column of water in a common pump, *the measure of that power must be the weight of the column of water;* and consequently, if another liquid be used, heavier or lighter, bulk for bulk, than water, *then the same force must sustain a lesser or greater column of such liquid.* By using a much heavier liquid, the column sustained would necessarily be much shorter, and the experiment in every way more manageable.

Torricelli verified his conclusions in the following manner:—He selected for his experiment mercury, the heaviest known liquid. As this is 13½ times heavier than water,

Fig. 47.

he argued, that the column of mercury which would be sustained by a vacuum, must be 13½ times less than the height of a column of water sustained in like manner, or about 30 inches. He procured a glass tube A B (*fig.* 47) more than 30 inches in length, open at one end A, and closed at the other end B. Placing this tube with the open end upwards, he filled it with mercury, and applying his finger to the end A, so as to prevent the escape of the mercury, he inverted the tube, plunging the end A into the cistern C D (*fig.* 48), containing mercury; the open end A being below the surface F of the mercury in the cistern, and no air having been allowed to communicate with it. Upon removing the finger, therefore, the mercury in the cistern came in immediate contact with the mercury in the tube. Immediately the mercury was observed to subside from the top of the tube, and its surface gradually to descend to the level E, about 30 inches above the mercury in the cistern. The result was what Torricelli expected, and he soon perceived the true cause of the phenomena. The atmospheric pressure acting upon the surface F, while the surface E was protected from the pressure by the closed end B of the tube, supported the weight of the column E F. The pressure was transmitted by the liquid mercury in the cistern from the external surface F to the base of the column contained in the tube.

Fig. 48.



Q. How was the fact that the column of mercury was sustained by the PRESSURE OF THE ATMOSPHERE, further verified?

A. By an experiment made by *Pascal*, in France. He argued, that if the cause which sustained the column in the tube was the weight of the atmosphere acting on the external surface of the mercury in the cistern, then, if the tube was transported to the top of a high mountain, where a less quantity of atmosphere was above it, the pressure would be less, and the length of the column less. This was tried and found to be the case.

Q. How did these experiments lead to the invention of the BAROMETER?

A. It was noticed that when the apparatus above described was kept in a fixed position, *the height of the column fluctuated* from day to day within certain small limits. The effect was of course to be attributed to the variation in the weight of the incumbent atmosphere, arising from various meteorological causes.

This led to the use of the tube and cistern of mercury, arranged in the manner before described (*figs.* 47 and 48), for determining the changes in the atmosphere, and consequently the character of the weather.

Q. How can the BAROMETER be employed as a WEATHER GLASS?

A. By showing the variations in the *air*, it indicates the *change* in the *weather:* thus, when the air is *light* or *moist*, the mercury stands *low;* when the air is *heavy* and *dry*, the mercury *rises* in the tube.

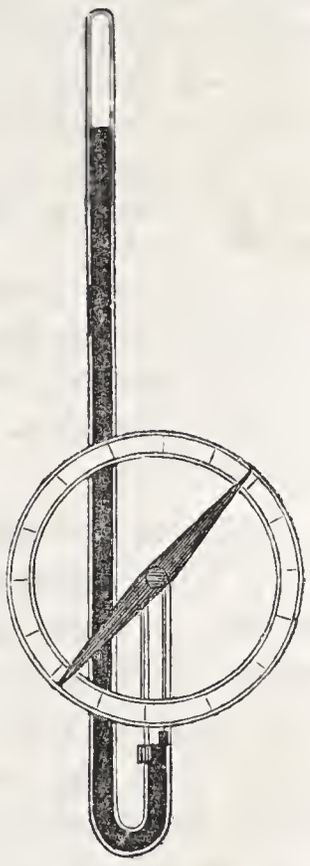
Q. How may the HEIGHT of MOUNTAINS be ascertained by the BAROMETER?

A. As we ascend a high mountain the quantity of air above us becomes less and less every step we ascend, and requires less mercury

to balance it; in consequence of which, the mercury in the tube of the barometer *falls*.

For general purposes, we may take this for a rule: for every one hundred feet of perpendicular height the barometer will fall one-tenth of an inch. If, therefore, the barometer has fallen one and a half inch, you know the mountain is fifteen hundred feet high.

Fig. 49.



Q. How is the common form of barometer, called the WHEEL barometer, constructed?

A. The barometer consists of a *bent tube*, filled with mercury, as represented in *fig.* 47, the column being sustained by the pressure of the atmosphere upon the surface of the mercury in the shorter arm, the end of which is open. A small float of iron or glass rests upon the mercury in the shorter arm of the tube, and is suspended by a slender thread, which is passed round a wheel carrying an index. As the level of the mercury is altered, and the weight raised or lowered in the tube, the index moves; and as the divisions on the circumference of the circles within which it moves are much amplified, very slight changes are easily read off.

Q. Why is the ordinary use of the barometer on the LAND extremely limited and uncertain?

A. The height of the mercury in the tube at any time must depend partially upon the *elevation of the place of observation above the level of the sea;* and no correct judgment can be formed relative to the density of the atmosphere as affecting the state of the weather without reference to the situation of the instrument at the time of making the observation. Therefore, no attention ought to be paid to the words, "*fair*, *rain*, *changeable*," &c., frequently engraved on the plate of a barometer, as they will be found no *certain* indications of the correspondence between the heights marked, and the state of the weather.

Q. What RULES, in observing by the barometer, may generally be relied on?

A. 1.—Generally the *rising* of the mercury indicates the approach of *fair* weather; the *falling* of it shows the approach of *foul* weather.

2.—In sultry weather the fall of the mercury indicates coming thunder. In winter the rise of the mercury indicates frost. In frost its fall indicates thaw; and its rise indicates snow.

3.—Whenever a change in the weather suddenly follows a change in the barometer, it may be expected to last but a short time. Thus, if fair weather immediately follows the rise of the mercury, there will

be very little of it; and, in the same way, if foul weather immediately follows the fall of the mercury, it will last but a short time.

4.—If fair weather continues for several days, during which the mercury continually *falls*, a *long succession of foul weather* will probably ensue; and, again, if foul weather continues for several days, while the mercury continually *rises*, a *long succession of fair weather* will probably succeed.

5.—A fluctuating and unsettled state in the mercurial column indicates changeable weather.

Q. The inhabitants upon the elevated plains of South America have LARGER CHESTS than the dwellers in the plains below. What good purpose in the animal economy is apparent here?

A. The air upon these high plains is *greatly rarefied;* and a person, although expanding his chest as much as usual, really takes in at each inspiration *only half as much air as he does* when in a less elevated situation. This inconvenience is removed by an expansion of the chest.

Q. Explain the DIFFERENCE between the THERMOMETER and BAROMETER.

A. The mercury in a *barometer* is left exposed, and rises or falls according to the density of the air. In a *thermometer* the mercury is sealed up, and rises or falls as the air contracts or expands it.

Q. Why is the TUBE of a BAROMETER left open?

A. That the air may *press upon it* freely; and, as this pressure varies, the mercury *rises or falls* in the tube.

Q. Why does the mercury in the barometer rise at the approach of FAIR WEATHER?

A. Because the air is becoming *more dry*, and the drier the air, and the more free it is from vapour, the greater the pressure.

Q. Why does the mercury SINK at the approach of FOUL weather?

A. Because the air is *laden with vapour* or *disturbed by wind.*

Q. Why does VAPOUR in the air cause the mercury to sink?

A. Because air containing vapour is *lighter than dry air;* and its pressure on the mercury is therefore less.

Q. Why will there be NO RAIN if the AIR be very DRY?

A. Because *dry* air will *absorb moisture*, and not part with it in *rain.*

Q. Why will there be NO RAIN if the AIR be very COLD?

A. Because it is *so much condensed*, that it has already parted with as much moisture as it can spare.

Q. When does the barometer VARY MOST?

A. In winter-time.

Q. Why is there a greater VARIATION in the barometer in WINTER than in SUMMER?

A. Because a greater disturbance is produced in the air, the difference of temperature in the temperate and torrid zones being greater in winter than in summer.

Q. Why does the barometer VARY LESS in summer than in winter?

A. Because the temperature is *more equal*, being less disturbed by currents in the torrid and temperate zones.

Q. What effect have HEAT and COLD on the barometer?

A. Of themselves they have no effect: but because warm weather is often *moist*, the mercury sinks; because cold weather is generally dry, the mercury rises. The moisture in the atmosphere is the occasion of the changes indicated.

ACOUSTICS.

—✦—

CHAPTER XIII.

ORIGIN AND TRANSMISSION OF SOUNDS.

Q. Of what PHENOMENA does the SCIENCE of ACOUSTICS treat?

A. Of the *causes and effects of sound*, and of the manner in which it is perceived by the organs of hearing.

Q. How is SOUND produced?

A. Sound is heard where any sudden shock or impulse, *causing vibrations*, is given to the air, or any other body, which is in contact, directly or indirectly, with the *drum of the ear.*

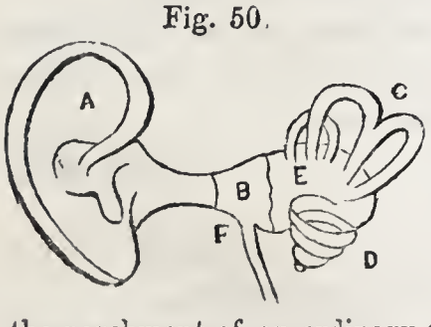
Q. What is the DRUM or TYMPANUM of the EAR?

A. A *thin membrane* which closes the aperture of the ear.

Q. How do the VIBRATIONS of the AIR, striking upon the DRUM of the EAR, give us the sensation of sound?

A. Behind the drum of the ear are various *cavities* and *tubes* in the bone which form the side of the head, in which the *minute fibres of the auditory nerve are distributed.* When the drum of the ear is made to vibrate freely by the action of the sonorous undulations of the external air, the vibrations are communicated by the action of minute bones, muscles, and fluids, contained in the cavities of the ear to the nerve, and from thence the impressions are conveyed to the brain.

Fig. 50.



THE ANIMAL EAR (*See fig.* 50).—The parts of the ear and the progress of sound to the sentient nerve may be simply described as follows:—1. There is external to the head a wide-mouthed tube, or ear-trumpet, *a*, for catching and concentrating the waves of sound. It is movable in many animals, so that they can direct it to the place from which the sound comes.

2. The sound concentrated at the bottom of the ear-tube falls upon a membrane stretched across the channel, like the parchment of an ordinary drum, over the space called the *tympanum*, or *drum of the ear*, *b*, and causes the membrane to vibrate. That its motion may be free, the air con-

tained within the drum has free communication with the external air by the open passage, *f*, called the *eustachian tube*, leading to the back of the mouth. A degree of deafness ensues when this tube is obstructed, as in a cold; and a crack, or sudden noise, with immediate return of natural hearing, is generally experienced when, in the effort of sneezing or otherwise, the obstruction is removed.

3. The vibrations of the membrane of the drum are conveyed farther inwards, through the cavity of the drum, by a chain of four bones (not here represented on account of their minuteness), reaching from the centre of the membrane to the *oval door* or *window* leading into the labyrinth *e*.

4. The labyrinth, or complex inner compartment of the ear, over which the nerve of hearing is spread as a lining, is full of watery fluid; and, therefore, by the law of fluid pressure, when the force of the moving membrane of the drum, acting through the chain of bones, is made to compress the water, the pressure is felt instantly over the whole cavity. The labyrinth consists of the *vestibule*, *e*, the three *semicircular canals*, *c*, imbedded in the hard bone, and a winding cavity, called the *cochlea*, *d*, like that of a snail-shell, in which fibres, stretched across like harp-strings, constitute the *lyra*. The separate uses of these various parts is not yet fully known. The membrane of the tympanum may be pierced, and the chain of bones may be broken, without entire loss of hearing.—ARNOTT.

Q. Is AIR necessary to the production of sound?

A. No; but most sounds owe their origin to the vibrations of the air. Sound can be produced *under water*, and *all bodies* are, in fact, more or less fitted to *produce the sound vibrations;* in many cases air is neither the quickest nor the best conductor of sound.

Q. Upon what does the LOUDNESS of SOUND conveyed by air depend?

A. Upon the *density* of the air.

Q. Why does a bell rung in a receiver exhausted of air FAIL to produce SOUND?

A. Because *no air* is present to receive and transmit the vibrations.

Q. Why is a whisper heard with greater distinctness in a DIVING-BELL?

A. Because the air in the diving-bell is *greatly condensed* by the pressure of the water, and *receives* and *transmits* the vibrations with great readiness.

Q. Why are MOUNTAINS NOISELESS and quiet?

A. Because the air of mountains is *very rarefied;* and, as the air becomes *rarefied*, sound becomes less *intense.*

Q. How can we prove that liquids conduct sound?

A. A person diving under water would plainly hear the sound of a bell struck in the air at a moderate distance above. If both the hearer and the sounding body be immersed in the same mass of water, the sound will appear much louder than when passing through an equal extent of air.

Q. How is the propagation of sonorous vibrations in LIQUIDS rendered visible?

A. By *rubbing* gently with a wet finger the edge of a drinking-glass half filled with water, sound will be produced, and the surface of the water will be covered with minute undulations.

Q. According to what circumstances does the POWER of LIQUIDS to conduct sound depend?

A. The intensity or loudness of sound in fluids appears to be augmented in proportion to their *increase in specific gravity.*

Thus, water being a fluid so much denser than air, sounds produce a stronger effect in

the former medium than in the latter. It is therefore a wise provision of the Creator, that the organs of hearing in fishes are much less perfectly developed, and consequently less sensible to the impressions of sound, than those of terrestrial animals.

Q. What are SONOROUS bodies ?

A. Bodies which *produce sound* are called sonorous bodies.

Q. Why are SOME things SONOROUS and others NOT ?

A. The sonorous quality of any substance depends upon its *hardness and elasticity.*

Q. Why are IRON and COPPER SONOROUS ?

A. Because these metals are hard and elastic; lead being neither elastic nor hard, is not sonorous.

Q. Of what is BELL-METAL made ?

A. Of *copper* and *tin* in the following proportions:—In every five pounds of bell-metal there should be one pound of tin and four pounds of copper.

Q. Why is BELL-METAL composed of tin and copper ?

A. Because the union of these metals produces a combination much harder and more elastic than could be obtained by simply using one metal alone.

Q. How does the conducting power for sound possessed by ELASTIC SOLIDS compare with that of other CLASSES of BODIES ?

A. *Solids*, when they possess *elasticity*, convey sounds to the ear more readily and effectively than *gases or liquids.*

Q. In what manner may a person PARTIALLY DEAF be enabled to carry on a conversation readily ?

A. If he places one end of an iron rod between his teeth while the other end rests on the edge of an open kettle, he will understand what is said by a person directing his voice into the kettle more distinctly than if the voice of the speaker passed through the air; so that he might converse with any one in this manner at a distance at which he would not hear under ordinary circumstances.

Q. What easy EXPERIMENT illustrates the transmission of sounds by solids ?

A. When a stick is held between the teeth at one extremity, and the other is placed in contact with a table, the scratch of a pin on the table may be heard with great distinctness, though both ears be stopped.

Q. How does the EAR TAKE cognisance of sounds propagated in THIS MANNER ?

A. There is a passage called the *eustachian tube*, which extends from the back part of the mouth to the cavity immediately behind the drum of the ear, through which the air passes. The sound vibrations are transmitted along this tube to the interior part of the organs of hearing.

Q. What plan do SAVAGES adopt to hear the APPROACH of an ENEMY or BEAST OF PREY ?

A. They place their ears to the *ground*, and by this means can distinguish clearly the approach of an enemy.

Q. What kind of SURFACES are best adapted for the TRANSMISSION of SOUND ?

A. *Smooth surfaces*, such as ice, water, or hard ground.

Q. To what useful contrivance has the PRINCIPLE that solids convey sounds more perfectly than air been applied?

A. To the construction of the *stethoscope*, or *chest inspector.*

Q. What is a STETHOSCOPE?

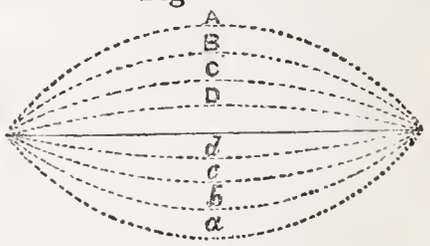
A. It is a *wooden* instrument which resembles a small *trumpet.* The wide mouth is applied to the body, and the other is held to the ear of the physician, who can hear distinctly the action of the lungs, and judge whether they be healthy or the reverse.

Q. Why has the peculiar kind of motion in bodies which gives rise to the sensation of sound, been termed VIBRATION?

A. Because a striking analogy may be traced between the tremulous agitation which takes place among the particles of a *sounding body* and the *oscillations* of a *pendulum.*

Q. How may the NATURE of sonorous vibrations be illustrated?

Fig. 51.



A. By noticing the visible motions which occur on striking or twitching a *tightly extended cord* or *wire.* Suppose such a cord, represented by the central line in *fig.* 51, to be forcibly drawn out to A, and let go; it would immediately recover its original position by virtue of its elasticity; but when it reached the central point, it would have acquired so much momentum as would cause it to pass onward to *a;* thence it would vibrate back in the same manner to B, and back again to *b*, the extent of its vibration being gradually diminished by the resistance of the air, so that it would at length return to a state of rest.

Q. What purpose is subserved by the BODY of a STRINGED INSTRUMENT?

A. The *string* of an *instrument* when caused to vibrate, communicates the vibrations to the matter composing the body of the instrument and the surrounding air, and thus a *tone* or *musical note* is produced and rendered audible to the ear.

Q. How are AERIAL VIBRATIONS OR PULSES communicated?

A. The air, encompassing sounding bodies on every side, conveys the sensation of sound in all directions; therefore the *aerial vibrations*, or, as they have been termed, "*pulses*," must be communicated successively and generally throughout the whole space within the limits of which they are capable of affecting the ear.

Q. To what have the SOUND, VIBRATIONS, or PULSATIONS been compared?

A. To the *waves* spreading in concentric circles over the smooth surface of water.

When a stone is thrown into water, the liquid waves are propagated not only directly forward from the centre, but if they encounter any obstruction, as from a floating body, they will bend their course round the sides of the obstacle, and spread out obliquely beyond it. So the undulations of air, if interrupted in their progress by a high wall or other similar impediment, will be continued over its summit and propagated on the opposite side of it.

Q. Of what real nature are the movements of the waves of air ?

A. When the particles of air vibrate, the motion thus originated produces no permanent change of place among the particles of the sonorous mass, but simply an *agitation* or *tremor*, so that each particle, like a pendulum which has been made to oscillate, recovers at length its original position.

This motion may be best illustrated by comparing it to the motion produced by the wind in a field of grain. The grassy waves travel visibly over the field in the direction in which the wind blows; but this appearance of an object moving is only delusive. The only real motion is that of the heads of the grain, each of which goes and returns as the stalk stoops or recovers itself. This motion affects successively a line of ears in the direction of the wind, and affects simultaneously all the ears of which the elevation or depression forms one visible wave. The elevations and depressions are propagated in a constant direction, while the parts with which the space is filled only vibrate to and fro. Of exactly such a nature is the propagation of sound through air.

Q. What curious WAVE PHENOMENA may be noticed when a steamboat is passing very near the shore ?

A. If a point is observed in *advance of the boat*, as a stone on the beach, or a plant on the bank, it will be seen, long before the boat arrives opposite that point, that the water recedes considerably, and that this recession increases as the boat passes.

Q. How is this EFFECT produced ?

A. The paddle-wheels throw back the water, and form a *trough* or *hollow*, into which the water in advance of the boat rushes; and this increases with the speed at which the paddle-wheels are driven.

Q. Why do LARGE WAVES always follow in the TRACK of an advancing STEAMBOAT ?

A. Because the *levels of the water* before and behind the boat are *altered*, and the *effort to restore horizontality* produces a series of large waves. These waves spreading, break at length against the bank, and submerge the point which had previously been dry. Where rushes grow in the water, these wave motions are rendered very striking by the movement of the plants.

Q. At what RATE does SOUND TRAVEL through the air ?

A. At the rate of 1,142 feet in a second, or 13 miles in a minute. Light has a much greater velocity than sound, and therefore we see the flash of a gun before we hear the report.

Q. How is a KNOWLEDGE of the VELOCITY of SOUND made applicable to the MEASUREMENT of DISTANCES ?

A. Suppose a flash of lightning to be perceived, and on counting the seconds that elapse before the thunder is heard, we find them to amount to $3\frac{1}{2}$; then, as sound moves 1,142 feet in a second, it will follow that the thunder-cloud must be distant $1{,}142 \times 3\frac{1}{2} = 3{,}997$ feet.

Q. If from an eminence you look down upon a long COLUMN of SOLDIERS marching to a band of music in front, those in the rear will step a little LATER than those some distance before them : can you explain the reason of this ?

A. Each rank steps, not when the sound is *made*, but when in its *progress* down the column at the rate of 1,142 feet in a second of time, it reaches their ears. Those who are *near* the music hear it

first, while those at the end of the column must wait until it has *travelled* to their ears at the above rate.

Q. Why do we use SPEAKING-TUBES for transmitting SOUND?

A. Sound decreases in intensity from the centre where it originates, according to the same law as gravitation; that is to say, at double the distance it is only one-fourth part as strong; at three times the distance, a ninth; and so on. By confining it in tubes, which prevents its spreading, its force diminishes much less rapidly, and it will therefore extend to much greater distances.

Q. Why will a person at the extremity of a very long IRON PIPE or WIRE hear the same sound, made at the other extremity of the pipe or wire, twice?

A. Because the *air is not so good a conductor* of sound as the *iron;* therefore it passes along the metal almost instantaneously, but requires more time to travel the same distance through the air.

Q. What is the cause of WINDOWS RATTLING when carriages or carts are passing by?

A. The air communicates a vibration to the glass, and the window-frame being shaken adds to the noise.

Q. Why do we HEAR a BELL if it be STRUCK?

A. The bell *vibrates*, and in its agitation *compresses* the air to a certain distance around it at each vibration. The compressed air instantly *expands*, and in doing so repeats the pressure on the air next in contact with it, and so on; as a pebble thrown into still water makes waves all around it, diminishing in force the more distant they are from the original stroke. The air thus agitated reaches the ear, where a similar impulse is given to the membrane, and the mind then receives the impression of *sound.*

Q. How can a bell which is solid be said to vibrate?

A. Although the metal of which the bell is composed is solid, yet it actually changes its form every time it is struck, and its particles are thrown into motion.

Q. Is the SOUND of a bell STOPPED by TOUCHING it?

A. The sound is stopped by the bell ceasing to vibrate; any weight stopping the vibrations of the bell.

Q. After striking a finger-glass, why is the SOUND SILENCED upon touching the glass with the finger?

A. Because the pressure of the finger stops the *vibrations* of the glass; and, so soon as the finger-glass *ceases to vibrate*, it ceases to make sound-waves in the air.

Q. Why is a hoarse sound produced by a SPLIT BELL?

A. It is occasioned by a double vibration, which makes the sound-waves jar, and produces a discordant noise.

Q. Why are the BELLS of distant churches SOMETIMES heard better than at OTHERS?

A. It is owing to the state of the atmosphere; sound travelling much more rapidly when the air is cold and clear.

Q. Why can we hear distant CLOCKS best in COLD WEATHER?

A. Because sound travels more rapidly under such circumstances:

on the same account, voices of men can be heard for more than a mile in the cold air of the Arctic regions.

Q. Why are not SOUNDS heard more distinctly in FROSTY than in WARM WEATHER?

A. The air is more uniform, less rarefied, consequently a better conductor, and less liable to accidental currents.

Q. Why does a THICK MIST or HAZE prevent the distinct transmission of distant SOUNDS?

A. The air being laden with mist is of less uniform density, thus obstructing the sound-waves in their course.

Q. Why are SOUNDS HEARD better by NIGHT than DAY?

A. Night is more still, owing to the suspension of business, and the air is of more uniform density.

Q. Why is the air of more UNIFORM DENSITY by NIGHT than it is by DAY?

A. Because it is less liable to accidental currents; inasmuch as the breezes (created by the action of the sun's rays) generally *cease* during the night.

Q. Why does the sea HEAVE and SIGH just PREVIOUS to a STORM?

A. Because the density of the air is *very suddenly diminished*, and (as the density of the air is diminished) its power to transmit sound is diminished also; in consequence of which the *roar* of the sea is less audible, and seems like heavy sighs.

Q. Why is the AIR so universally QUIET just PREVIOUS to a TEMPEST?

A. Because the air is *suddenly* and very greatly *rarefied;* and (as the density of the air is diminished) its power to *transmit sound* is diminished also.

Q. Why does a railway TRAIN make more noise when it passes over a bridge, than when it runs over SOLID GROUND?

A. Because the bridge is *elastic*, and *vibrates* much more from the weight of the train than the solid earth; in consequence of which it produces more definite sound-waves.

The bridge acts as a sounding-board, and the water or earth below the bridge *repeats* the sound.

Q. Why can SOUNDS be heard (in a calm day) at a GREATER DISTANCE on the sea than on the land?

A. The plane surface of water, *as a smooth wall*, prevents the lateral spreading and dispersion of the sound-waves, although on only one side. The air over water, owing to the presence of moisture, is also generally more dense, and the density more uniform than over the land. Water, in addition, is a better conductor of sound than the earth.

Q. How should PARTITION WALLS be constructed so as to PREVENT the transmission of sound?

A. Shavings or sawdust should be put between the laths, so as to form several different media for the sound to pass through, and thus occasion as much obstruction as possible, and a consequent diminution of the strength of the sound-waves.

Q. Why does sound seem LOUDER in a CAVE than on a plain?

A. Because the sides of the cave confine the sound-waves, and prevent their spreading; in consequence of which their *strength* is greatly increased.

Q. What SOLIDS are among the BEST CONDUCTORS of SOUND?

A. *Iron and glass;* sound is transmitted by them at the rate of 17,500 feet, or more than three miles in a second; after these rank copper, several different kinds of wood, silver, tin, &c.

SECTION I.—VOCAL AND MUSICAL SOUNDS.

Q. What are MUSICAL SOUNDS?

A. Regular and uniform successions of vibrations.

Q. What is the difference between a MUSICAL SOUND and a mere noise?

A. All mere noises are occasioned by *irregular impulses* communicated to the ear; but, in order to produce a musical sound, the *impulses*, and consequently the *undulations* of the air, must be all exactly similar in *duration* and *intensity*, and must recur after exactly *equal intervals of time.*

Q. What do we mean by TONE or PITCH in sound?

A. If the sound impulses be repeated at very short intervals, the ear is unable to attend to them individually, but hears them as a continued sound, which is uniform, or has what is called a *tone* or *pitch*, if the impulses be *similar* and at *equal intervals.*

Q. Explain the production of TONE more fully.

A. If a wheel with teeth be made to turn and strike any elastic plate, as a piece of quill, with every tooth, it will, when moved slowly, allow every tooth to be seen, and every blow to be heard, separately; but, with increasing velocity, the eye will lose sight of the individual teeth, and the ear, ceasing to perceive the separate blows, will at last hear only a smooth, continued sound, *the tone*, *the character*, or *pitch* of which will change with the velocity of the wheel.

Q. When is a TONE said to be GRAVE or SHARP?

A. When the impulses are *few in a given time*, the tone is *grave;* when they *are many*, the tone is *sharp.*

Q. Why are SHARP SOUNDS generally LOUD SOUNDS?

A. Because to produce a sharp sound there must be *quick vibrations*, which are produced by forcible impulses; hence the sound is generally loud.

Q. Do ALL PERSONS hear sounds ALIKE?

A. No; that faculty seems to depend upon the *sensibility of the auditory nerves.*

"*Auditory*"—having the power of hearing.

Q. What are the BOUNDARIES of HUMAN HEARING?

A. The whole range of human hearing, from the lowest note of the organ to the highest known cry of insects, as of the cricket, includes about nine octaves.

All ears, however, are by no means gifted with so great a range of hearing; many persons, though not at all deaf, are quite insensible to the highest notes of some insects.

Q. How many VIBRATIONS of a musical chord are necessary to produce a DEFINITE SOUND?

A. It is generally believed that a vibrating chord will not produce a sound distinctly appreciable by the most delicate ear when it makes *less than thirty-two vibrations in a second.* It has, however, been asserted that a perceptible sound can be produced by a chord giving eight single vibrations in a second.

Q. How MANY VIBRATIONS is the human ear able to APPRECIATE?

A. The human ear is capable of appreciating as many as *twenty-four thousand vibrations* in a *second of time;* and is, consequently, able to hear a sound which only lasts the *twenty-four thousandth part of a second!*

Q. Are vibrations more frequent than TWENTY-FOUR THOUSAND in a second of time produced in nature?

A. Certainly; vibrations incomparably more rapid undoubtedly exist.

Q. Why do we not hear sounds INDEFINITELY above this limit?

A. On account of the peculiar constitution of the human ear and nervous system.

While we have *no proof* that other animals are capable of perceiving sounds of which the human ear can take no cognisance, there are some reasons for supposing that animals, like the crickets or grasshoppers, whose powers appear to commence where ours terminate, may hear sharper sounds which we do not know to exist; and there may be insects hearing nothing in common with us, but endued with a power of exciting, and a sense that perceives, the same vibrations which constitute our ordinary sounds, but so different that the animal who perceives them may be said to possess another sense.

Q. How is it that some notes are TREBLE and others BASE?

A. The difference is attributable to the slow or quick vibration of the sound-wave; *treble* notes are produced by *quick* vibrations, *base* notes by *slow* vibrations.

Q. What occurs when of several sonorous bodies, near each other, and tuned to one accord, ONE is thrown into a state of vibration?

A. All others near it, capable of producing the same tone, will *vibrate also.*

Q. How are WEAK SOUNDS affected by the occurrence of more powerful ones in their vicinity?

A. When one body is made to produce a certain note, its soniferous vibrations will be checked or interrupted by the emission of *a more powerful* or *discordant sound* near it. Hence weak sounds are generally drowned by loud ones.

Q. What is meant by "A MUSICAL EAR?"

A. The faculty of *distinguishing certain relations* between sounds

differing in tone—that is, sounds which are more or less grave or acute than others.

Q. What is meant by the terms CONCORD and DISCORD?

A. When two tones or notes sounded together produce an agreeable effect on the ear, their combination is called a *musical concord;* when the effect is disagreeable, it is called a *discord.*

Q. What is the GAMUT or DIATONIC SCALE of music?

A. It consists of *seven notes*, which are distinguished by the seven first letters of the alphabet, or by the seven syllables *do*, *re*, *mi*, *fa*, *sol*, *la*, *si.*

Q. Two waves of water may undulate in such a manner as TO DESTROY EACH OTHER; can two sonorous waves be made to move in such a manner as to PRODUCE SILENCE?

A. They can; if two volumes of sound are produced at the same time, they give rise to a sound *double the strength* of either separately; and, as in the case of water-waves, the undulations coincide, and meet at the point of greatest elevation, to swell into one note. Now, if we so regulate the vibrations of one sound that it is not in unison with another (the difference, however, between them being very slight), the quicker vibrations of the one will overtake the slower vibrations of the other; and, at a certain vibration, the depression of one wave will be filled with the elevation of the other, and no sound is heard; absolute silence results, and at intervals in the vibrations the absence of sound recurs.

Q. Into what FOUR CLASSES are MUSICAL INSTRUMENTS divided?

A. Into *stringed instruments*, as the violin, harp, &c.; *pulsatory instruments*, as bells, gongs, drums, &c.; *instruments* in which the sound depends on the *vibrations of elastic rods or plates*, as the harmonicon, musical glasses, &c.; and *wind instruments*, as the trumpet, bugle, &c.

Q. How are musical sounds produced by a PIANO-FORTE?

A. The keys of the instrument lift small hammers on being struck with the fingers, which hammers strike the strings of the piano, and by vibration set in motion the sound-waves.

Q. How is it that a DRUM is made to sound?

A. The blows of the drum-sticks on the parchment cause the air to vibrate, and consequently produce sound.

Q. How do MUSICAL GLASSES, VIOLINS, and FLUTES occasion SOUND?

A. On the same principle of vibration. In the *flute* the air is caused to vibrate by the *breath* of the performer, in the *violin* the bow being drawn across the *strings*, produces vibration. *Musical glasses* vibrate as soon as struck, and so agitate the sound-waves of the air.

Q. Why is an instrument FLAT when the STRINGS are UNSTRUNG?

A. Because the vibrations are *too slow;* in consequence of which the sounds produced are not *shrill* or *sharp* enough.

Q. Why do BIRDS alone, of animals, produce MUSICAL NOTES?

A. Because they alone are gifted with a *vocal organisation*, which enables them to produce musical notes. In other animals, the larynx is placed wholly at the upper end of the windpipe; but in birds it is separated, as it were, into two parts, one placed at each extremity.

Q. Why cannot birds be so correctly said to SING as to WHISTLE?

A. Because natural singing is an exclusive privilege of man.

Q. Why do the notes of different species of birds vary?

A. Because, probably, of the structure of the organs of each species enabling them more easily to produce the notes of their own species than those of any other, and from the notes of their own species being more agreeable to their ears. These conditions, joined to the facility of hearing the song of their own species, in consequence of frequenting the same places, determine the character of the acquired language of the feathered tribes.

Q. Why does one sex only of birds sing?

A. Because, as Buffon supposed, of cheering his mate during the period of incubation; but this idea, gallant as it is, has but slight foundation in probability. The singing of most birds seems entirely a spontaneous effusion, produced by no exertion, or occasioning no lassitude of muscle, or relaxation of the parts of action. In certain seasons and weather, the nightingale sings all day and most part of the night; and we never observe that the powers of song are weaker, or that the notes become harsh and untunable after these hours of practice. The cuckoo is probably the only bird that seems to suffer from the use of the organs of voice.

Q. In the human system, what are the PARTS concerned in the production of SPEECH and MUSIC?

A. They are the *windpipe*, the *larynx*, and the *glottis*.

Q. What is the WINDPIPE?

A. The windpipe is merely a cartilaginous canal through which the air issues from the lungs.

Q. What is the LARYNX?

A. The *larynx* is an *enlarged continuation of the windpipe*, formed, like it, of *cartilage*, or *gristle*, *membrane*, and *muscle;* it is, however, more complicated, terminating above in two lateral membranes which approach near together, leaving an oblong, narrow opening, called the *glottis*.

Q. How is SOUND produced by the ORGANS of VOICE?

A. The *air* expired from the *lungs* passes through the *windpipe* and out at the *larynx*, through the opening of the membrane called the *glottis*. The vibration of their membranes, caused by the passage of air, causes sound.

Q. How can the TONES of the VOICE be made GRAVE or ACUTE?

A. By varying the *tension* of these membranes and the *size* of the opening.

Q. What is the FORCE exerted by the HEALTHY CHEST in BLOWING?

A. To about *one pound on the inch of its surface;* that is to say, the chest can condense its contained air with that force, and can therefore blow through a tube the mouth of which is ten feet under the surface of water.

Q. What is the VOCAL ACTION of COUGHING?

A. In coughing, the top of the windpipe or the glottis is *closed for an instant*, during which the chest is compressing and condensing its contained air; and on the glottis being opened, a *slight explosion*, as it were, of the compressed air takes place, and blows out any irritating matter that may be in the air-passages.

Q. Why does a POP-GUN make a loud report when the paper bullet is discharged from it?

A. Because the air confined between the paper bullet and the discharging rod is suddenly liberated, and strikes against the surrounding air; this makes a report in the same way as when any two *solids* (such as your hand and the table) come into collision.

Q. What is SNEEZING?

A. Sneezing is a phenomenon resembling cough; only the chest empties itself at one effort, and chiefly through the *nose*, instead of through the *mouth*, as in coughing.

Q. What is LAUGHING?

A. Laughing consists of *quickly repeated expulsions of air* from the chest, the glottis being at the time in a condition to produce voice; but there is not between the expirations, as in coughing, a complete closure of the glottis.

Q. What is HICCOUGH?

A. Hiccough is the *stopping* of the commencement of a strong inspiration, by a *sudden closing* of the *glottis.*

Q. What is CRYING?

A. Crying differs from laughing almost solely in the circumstance of the *intervals between the gusts* or *expirations* of air from the lungs *being longer.* Children laugh and cry in the same breath.

Q. Why, in STRAINING to LIFT WEIGHTS, or to make any powerful bodily effort, do we COMPRESS our BREATH?

A. We shut up the air in the lungs in order to give *increased steadiness* and *firmness* to the body.

Q. When is a PERSON SUFFOCATED?

A. When the *windpipe becomes choked*, or the supply of air to the lungs is in any way cut off.

Q. Why do birds sing comparatively LOUDER than man?

A. Because the *strength* of the larynx, and of the muscles of the throat, in birds, is infinitely greater than in the human race. The loudest shout of man is but a feeble cry compared with that of the golden-eyed duck, the wild-goose, or even the woodlark.

Q. How are WINGED INSECTS generally found to produce SOUND?

A. Generally, they excite sonorous vibrations by the *fluttering of their wings*, or other membranous parts of their structure.

Q. How does the LOCUST produce SOUND?

A. They are furnished with an *air-bladder*, or species of *bagpipe*, placed under and rather behind their wings.

SECTION II.—REFLECTION OF SOUND.

Q. What is ECHO?

A. Echo is *reflected* sound.

Q. What is the CAUSE of ECHO?

A. When a wave of water strikes against a smooth wall or obstacle, it turns back; so that, at any distance after the reflection, it appears as it would have been at the same distance beyond the wall, only moving in an opposite direction; so the *pulses or waves of sound* are *regularly reflected* from flat surfaces, and produce what is called an echo.

Q. Why are caverns, grottoes, and ruins FAMOUS for ECHOES?

A. Because the sound-waves *cannot flow freely forward*, but perpetually strike against the winding walls, and are beaten back.

Q. Why are MOUNTAINS and icebergs FAMOUS for ECHOES?

A. Because they present a *barrier* to the sound-waves, *which they cannot pass*, and are sufficiently elastic to *throw them back.*

Q. What BEAUTIFUL FICTION existed among the ancients relative to the production of ECHO?

A. They supposed that *Echo* was a *nymph* who dwelt concealed among the rocks, and who repeated the sounds she heard.

Q. At what DISTANCE must the BODY reflecting the sounds be situated in order to produce an ECHO?

A. It is requisite that the reflecting body should be situated at such a distance from the source of sound, *that the interval between the perception of the original and reflected sounds may be sufficient to prevent them from being blended together.*

Q. When the SOUNDS become thus BLENDED together, what is the effect called?

A. A *resonance*, or resounding, and not an echo.

Q. What is the SHORTEST INTERVAL of SPACE and TIME requisite to produce an echo?

A. The *shortest interval* sufficient to render sounds distinctly appreciable by the ear, is about one-tenth *of a second;* therefore when sounds follow at shorter intervals, they will form a resonance instead of an echo; so that no reflecting surface will produce a distinct echo, unless its distance from the spot where the sound proceeds is at least $56\frac{1}{2}$ feet; as the sound will in its progress forward and return through double that distance—113 feet—take up one-tenth of a second.

Q. Why do not the WALLS of a ROOM of ordinary size produce an echo?

A. Because the *reflecting surface* is so near the source of sound

that the echo is *blended with the original sound;* and the two produce but *one impression* on the ear.

Q. Why do LARGE buildings sometimes REVERBERATE to the sound of the human voice?

A. The walls being too far off from the speaker for the echo to combine with the original sound, each is separately heard.

Q. Why do SOME echoes repeat ONE syllable only and others TWO?

A. The difference is caused by the distance of the echoing body. The farther it is removed the more sound it reflects. If near, it repeats but one syllable; if further removed, two syllables are heard.

Q. Are not TWO ECHOES sometimes heard?

A. Two or more echoes are heard in some places, because separate reverberating surfaces receive the sound, and in succession reflect it. The Killarney echo plays a second to any simple tune, if distinctly played on a bugle.

Q. What must be the CONDITIONS of the REFLECTING SURFACE in order to produce a PERFECT ECHO?

A. The surface must be *smooth* and of some *regular form;* for the wave of sound rebounds, according to the same law as a wave of water or an elastic ball, *perpendicularly to the surface* if it fall perpendicularly, and if it fall *obliquely* on one side, it *departs with an equal degree of obliquity* on the other side.

Q. What must be the EFFECT of an IRREGULAR SURFACE?

A. An *irregular surface* must break the *echo;* and if the irregularity be very considerable, there can be no distinct or audible reflection at all. For this reason an echo is much less perfect from the front of a house which has windows and doors, than from the plane end, or any plane wall of the same magnitude.

Q. Why have HALLS for music PLANE BASE WALLS?

A. Because the *hard plane walls reflect the sound regularly*, and increase the effect of the music.

Q. Why are HALLS for SPEAKING, THEATRES, CHURCHES, &c., generally ornamented on the wall, and furnished with PILLARS, CURTAINS, &c.

A. Because the *ornaments*, *pillars*, *curtains*, &c., form *irregular surfaces*, which *break* up and *destroy* the echoes and resonances.

Q. Why is a THICK CURTAIN often placed behind a PULPIT or SPEAKING-DESK?

A. Because the *material absorbs the sound*, and by not reflecting it avoids the production of echoes and resonances.

If the room is not very large, a curtain behind the speaker impedes rather than assists his voice.

Q. In CONSTRUCTING a ROOM for PUBLIC SPEAKING, what ought to be the LIMIT of HEIGHT of the CEILING?

A. Not above 30 or 35 feet.

Q. Why not ABOVE this LIMIT?

A. If we advance towards a wall on a calm day, producing at each step some sound, we will find a point at which the echo ceases to be distinguishable from the original sound. The distance from the wall, or the corresponding interval of time, has been called the *limit of*

perceptibility. This limit is about 30 to 35 feet; and if the ceiling of a building for speaking be arranged at this limit, the sound of the voice and the echo will blend together, and thus strengthen the voice of the speaker.

Q. What will be the effect if the CEILING be constructed HIGHER than the LIMIT of PERCEPTIBILITY?

A. The *direct sound* and the *echo* will both be *heard separately*, and *produce indistinctness.*

Q. Why is it that we are enabled to hear for a great distance SOUND communicated through a tube?

A. Because the *sides of the tube confine, or repress by a continued reflection*, the advancing sound, which in the open air would quickly spread laterally and be dissipated.

Q. What is the construction and use of an EAR-TRUMPET?

A. It is a tube wide at one end where the sound enters, and narrow at the other where the ear is applied. Its sides are so curved that *all the sound* that enters *is reflected* and *brought to a focus* at the narrow end. It thus increases many fold the intensity of the sound which reaches the ear through it, and enables a person who has become deaf to common conversation to hear tolerably well.

Q. Why do persons hold the HAND CONCAVE behind the EAR in order to hear more distinctly?

A. Because the concave hand acts in some respects as an *ear-trumpet*, and *reflects* the sound into the ear.

Q. Why does an INFLATED BLADDER, when BURST OPEN WITH FORCE, produce a SOUND like the report of a pistol?

A. Because sound, to some extent, always accompanies the *liberation of compressed air.*

Q. Why, when the SMOKE is projected from the lips of a TOBACCO-SMOKER, does a LITTLE EXPLOSION usually accompany the PUFF?

A. This sound appears to be chiefly due to the *sudden bursting of the film* which connects both lips; and the nature of the sound is, in a great measure, dependent upon the state of the lips at the time, whether they be *moist or dry.*

Q. Why does a STREAM of WATER, falling from one vessel into another, FLOW comparatively SILENTLY for a SHORT DISTANCE, and NOISILY if the distance BE INCREASED beyond a certain limit?

A. When the distance which the water falls is so limited that the *end of the stream does not become broken into bubbles or drops*, neither air-bubbles nor sounds will be produced; but as soon as the distance becomes increased to an extent sufficient to *break the end of the column into drops*, both air-bubbles and sounds will be produced. The sound of falling water appears, therefore, to be in a great measure owing to the formation and bursting of the bubbles.

HEAT.

CHAPTER XIV.

NATURE AND SOURCES OF HEAT.

Q. What is HEAT?

A. The *sensation of warmth.*

Q. To what CAUSE have different philosophers attributed the PHENOMENON of HEAT?

A. Some have ascribed the phenomenon of heat to be merely a *species of motion* among the minute particles of bodies generally, as sound is motion of another kind among the same particles; others have supposed that heat arises from the *presence of a peculiar fluid or ethereal kind of matter*, such as that which has been regarded as the cause of light.

Q. What great FACT is opposed to the idea that heat has a SEPARATE MATERIAL EXISTENCE as a fluid?

A. The fact that nature nowhere presents us, neither has art ever succeeded in showing us, heat alone in a separate state.

Q. Has HEAT any PERCEPTIBLE WEIGHT?

A. No, if we balance a quantity of ice in a delicate scale, and then leave it to melt, the equilibrium will not be in the slightest degree disturbed If we substitute for the ice boiling water or red-hot iron, and leave this to cool, there will be no difference in the result.

Count Rumford, having suspended a bottle containing water, and another containing spirits of wine, to the arms of a balance, and adjusted them so as to be exactly in equilibrium, he found that it remained undisturbed when the water was completely frozen, though the heat the water had lost must have been more than sufficient to have made an equal weight of gold red-hot.

Q. What other FACTS are opposed to the supposition that heat has a SEPARATE EXISTENCE?

A. Heat can be produced without limit by *friction*, and *intense heat* is also produced by the *explosion of gunpowder.*

Q. Are there any facts which tend to show that heat has a SEPARATE and ISOLATED EXISTENCE?

A. Yes; the fact that it can be *communicated* very readily *through a vacuum;* that it becomes *instantly sensible* on the *condensation of any material mass*, as if it were squeezed out of it: as when, on reducing the bulk of a piece of metal by hammering, we render it very hot (the greatest amount of heat being emitted with the blows that most change its bulk), and, *finally*, that the *laws of the spreading of heat* do not resemble those of the spreading of sound, or of any other motion known to us.

Q. What important PROPERTY distinguishes heat from all other agents or substances in nature?

A. The property of *passing through* and *existing in all kinds of matter* at *all times;* heat is *everywhere present*, and every body that exists contains it *without known limit.*

Q. Has ICE heat?

A. Yes, large quantities of it. Sir Humphrey Davy, by friction, extracted heat from two pieces of ice, and quickly melted them, in a room cooled below the freezing-point, by rubbing them against each other.

Q. How do we MEASURE the QUANTITY of heat in different bodies, or judge of its effects?

A. Only by the *change in bulk* or *appearance* which different bodies assume, according as heat is added or subtracted.

Q. According to WHAT LAW does heat diffuse or spread itself?

A. Heat diffuses or spreads itself among neighbouring bodies *until all have acquired the same temperature;* that is to say, until all will similarly affect the thermometer.

Q. Why does a PIECE of IRON thrust into burning coals become HOT among them?

A. Because the heat passes from the coals to the iron until the metal has acquired an equal temperature.

Q. What is COLD?

A. Cold is a relative term expressing only the *absence of heat in a degree;* not its total absence, for heat exists always in all bodies.

Q. When the HAND touches a body having a HIGHER TEMPERATURE than itself, why do we call it HOT?

A. Because, on account of the law that heat diffuses itself among neighbouring bodies until all have acquired the same temperature, heat passes from the body of higher temperature to the hand, and causes a peculiar sensation, which we call *warmth.*

Q. Under what CIRCUMSTANCES do we call a body COLD?

A. When we touch a body having a temperature *lower than that of the hand*, heat, in accordance with the above law, passes out from the hand to the body touched, and occasions the sensation which we call *cold.*

Q. What, then, really are the SENSATIONS of HEAT and COLD?

A. Merely *degrees of temperature*, contrasted by name in reference to the peculiar temperature of the individual speaking of them.

Q. When may a body feel HOT and COLD to the SAME PERSON at the SAME TIME?

A. The sensation of heat is produced by a body colder than the hand, provided *it be less cold than the body touched immediately before;* and the sensation of cold is produced under the opposite circumstances, of touching a comparatively warm body, but which *is less warm than some other body touched immediately before.* Thus, if a person transfer one hand to common spring water immediately after touching ice, to that hand the water would feel very warm; while the other hand

transferred from warm water to the spring water would feel a sensation of cold.

Q. What is the RELATION between HEAT and LIGHT?

A. The relation between heat and light is a very intimate one. Heat exists without light, but *all the ordinary sources of light are also sources of heat;* and by whatever artificial means natural light is condensed, so as to increase its splendour, the heat which it produces is also, at the same time, rendered more intense.

Q. When is a BODY said to be INCANDESCENT OR IGNITED?

A. When the body naturally *incapable* of emitting light is heated to a sufficient extent to become *luminous.*

Q. What is FLAME?

A. A *luminous vapour* issuing from a burning body.

Q. What is FIRE?

A. The appearance of *heat and light in conjunction*, produced by the combustion of inflammable substances.

Q. What CHARACTER was attributed to fire by the ANCIENT PHILOSOPHERS?

A. They used the term *fire* as a characteristic of the matter of heat, and regarded it as one of the *four elements of nature.*

Q. Enumerate the general PHYSICAL PROPERTIES and PRINCIPAL EFFECTS of heat.

A. It is *invisible*, *without weight*, *elastic*, with great tendency to *expand*, and is *absorbed* by all bodies. Its principal effects are *expansion*, *liquefaction*, *vaporisation*, *and ignition.*

Q. What do we understand by the term CALORIC?

A. Caloric is the name given to the agent which produces the sensation of warmth; but *heat* is the *sensation itself.*

Q. Is CALORIC EQUALLY distributed over the globe?

A. No; at the *equator* the *average temperature* is $82\frac{1}{2}°$, while at the *poles* it is believed to be about 13° below zero.

"*Average Temperature*"—that is, the mean or medium temperature.

"ZERO"—the point from which a thermometer is graduated; it is 32° below freezing, Fahrenheit's thermometer.

Q. How many SOURCES OF HEAT are recognised to exist?

A. Six.

Q. What are they?

A. 1. *The sun;* 2. *The interior of the earth;* 3. *Electricity;* 4. *Vital action;* 5. *Mechanical action;* 6. *Chemical action.*

Q. To the existence of what NATURAL FORCE is CALORIC continually opposed?

A. It is constantly and directly antagonistic to the force of *cohesion.*

SECTION I.—THE SUN CONSIDERED AS A SOURCE OF HEAT.

Q. What is the PRINCIPAL SOURCE of NATURAL HEAT?

A. The *sun.*

Q. Does the HEAT of the SUN possess any different properties from ARTIFICIAL HEAT?

A. The heat of the sun *passes* readily *through glass*, whereas this

property is possessed by artificial heat in a *very small degree.* Solar heat also differs from artificial heat in some other minor points.

Q. What effect is produced when SUNBEAMS pass through a BURNING-GLASS ?

A. They are bent towards one point, the *focus*, when it is so concentrated as to set fire to natural substances.

Q. Is SUNSHINE detrimental to COMBUSTION ?

A. By many it is supposed to be, though nothing is positively known upon the subject. Fires never appear so bright when the sun shines full upon them.

Q. In what WAY have philosophers attempted to account for the production of HEAT and LIGHT by the SUN ?

A. Two opinions or theories have been entertained: one supposes that the sun is an *intensely heated mass*, which throws off its heat and light like an intensely heated mass of iron; the other supposes that heat is merely an *affection or state of an ethereal fluid*, which occupies all space, as sound is an affection or motion of the air; and that the sun may produce the phenomena of light and heat without waste of its temperature or substance, as a bell may constantly produce the phenomena of sound.

Q. What is the generally received opinion at present, in regard to the ACTUAL TEMPERATURE of the visible surface of the sun ?

A. That the *temperature* of its luminous coating is much *more elevated* than any *artificial heat* we are able to produce.

Q. Have we any positive knowledge concerning the physical condition of matter at the SURFACE of the SUN ?

A. Yes; experiments, conducted some years since by *Arago*, of France, settled the question to a most satisfactory extent.

Q. In WHAT MANNER was he enabled to do this ?

A. There are *two states* in which light is capable of existing—*the ordinary state* and the *state of polarisation.** It has been proved that all bodies, in a solid or liquid state, which are rendered incandescent by heat, emit *polarised light;* while bodies that are gaseous, when rendered incandescent, invariably emit light in its *ordinary state.*

Thus the physical condition of a body may be distinguished when it is incandescent, by examining the light which it affords. On applying the test to the direct light of the sun, it was found to be in the unpolarised or ordinary condition of light. Hence it has been inferred by Arago that the matter from which this light proceeds must be in the gaseous state, or, in other words, in the state of flame.

From other experiments and observations, Arago was led to the conclusion that the sun was a solid, opaque, non-luminous body, invested with an ocean of flame.

Q. Why is the heat of the SUN always greater in some portions of the earth than at others ?

A. Owing to the *position* of the *earth's axis*, the rays of the sun always fall *more directly* upon the central portion of the earth than they do at the poles or extremities.

Q. Upon what does the succession of SPRING, SUMMER, AUTUMN, and WINTER, and the variations of the temperature of the seasons, depend ?

A. Chiefly upon the *position* of the *sun* in relation to the earth.

* The term polarisation will be explained in a future chapter.

Q. When do we experience the greatest amount of HEAT from the RAYS of the SUN ?

A. When its rays fall *most perpendicularly.*

Q. Why is the heat of the SUN greatest at NOON ?

A. Because for the day the sun has reached the highest point in the heavens, and its rays fall *more perpendicularly* than at any other time.

Q. Why is it WARMER in SUMMER than WINTER ?

A. Because in summer the position of the sun is such that its *rays fall more perpendicularly* than at any other season. The sun is longer above the horizon in summer than in winter, and consequently imparts the greatest amount of heat.

Q. Why is it colder in winter than in summer ?

A. Because in the winter the position of the sun is such that its *rays fall more obliquely* upon the earth than at any other season. The sun is also for a less time above the horizon in winter than in summer, and consequently imparts less heat.

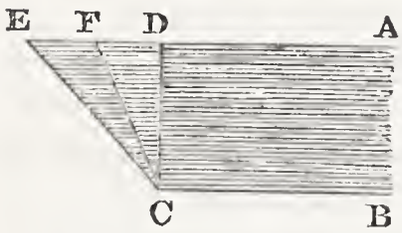
Q. Upon what does the HEATING POWER of the SUN chiefly depend ?

A. Upon its *altitude* or *height above the horizon;* the greater its altitude, the more perpendicularly will its rays fall upon the earth, and the greater their heating effect; the less the altitude, the more obliquely will its rays fall, and the less their heating effect.

Q. Why should the DIFFERENCE in the INCLINATION of the sun's rays falling upon the earth occasion a difference in their heating effect ?

A. Because the more the rays are inclined, the larger the space over which they fall.

Fig. 22.



Let us suppose A B C and D to represent a portion of the sun's rays; let C D represent a portion of the earth's surface upon which the rays would fall perpendicularly; and let C E represent that portion upon which they would fall obliquely; the same number of rays would strike the surface C D and C E; but the surface C E being obviously greater than C D, the rays will necessarily fall more densely on the latter; and, as the heating power must be in proportion to the density of the rays, it follows that C D will be heated more than C E, in just the same proportion as C E is greater than C D. But if we would compare two surfaces, on neither of which the sun's rays fall perpendicularly, let us take C E and C F. They fall on C E with more obliquity than C F; but C E is evidently greater than E F, and therefore, the rays being diffused over a larger surface, are less dense, and therefore less effective in heating.

Q. What is the greatest NATURAL HEAT ever observed ?

A. On the west coast of Africa the thermometer (Fahrenheit) has been observed as high as 108° *in the shade;* Burckhardt, in *Egypt*, and Humboldt, in *South America*, observed it at 117° F.; and, in 1819, at Bagdad, the thermometer rose to 120° F. in the shade.

Q. What is the LOWEST ATMOSPHERIC TEMPERATURE ever observed ?

A. 53° *below zero*, as observed by Dr. Kane; 58°, by Captain Parry; 60°, by Captain Ross; 71°, by Captain Back—all within the Arctic circle.

Q. What is the greatest ARTIFICIAL COLD ever produced ?

A. 135° *below zero*, which temperature was attained by Prof. Faraday. At this temperature, alcohol and ether did not freeze.

Q. What is the estimated temperature of the SPACE ABOVE the earth's atmosphere ?

A. 58° *below zero.*

Q. At what TEMPERATURE does MERCURY FREEZE ?

A. 38°·6 below zero.

Q. At what temperature does FRESH WATER FREEZE ?

A. At 32° *above zero.*

Q. At what temperature does SALT or SEA WATER FREEZE ?

A. At 28°·5 above zero.

Q. Why does it require a GREATER AMOUNT of COLD to cause SEA WATER to congeal, than it does FRESH WATER ?

A. Because *sea water* contains *salt* and other substances, which tend to prevent congelation.

Q. What is the average temperature at the EQUATOR ?

A. In *America*, 81°·5 ; in *Africa*, 83°.

Q. What is BLOOD-HEAT, or the vital temperature of the human body ?

A. 98°.

Q. At what TEMPERATURE does ALCOHOL boil ?

A. Under the ordinary atmospheric pressure at 173°·5.

Q. At what TEMPERATURE does WATER boil ?

A. Under the ordinary atmospheric pressure at 212°

Q. At what TEMPERATURE does LEAD melt ?

A. At 594°.

Q. At what heat does mercury boil ?

A. At 661° under the common atmospheric pressure.

Q. At what TEMPERATURE does BRASS, COPPER, SILVER, and GOLD melt ?

A. *Brass at* 1,869° ; *copper*, 1,996° ; *silver*, 1,873° ; *gold*, 2,016°.

Q. At what TEMPERATURE does CAST-IRON melt ?

A. At 2,786°.

Q. What is the greatest degree of ARTIFICIAL HEAT which we have been ENABLED TO MEASURE ?

A. A furnace heat of 3,280° : at this heat wrought-iron and platinum did not melt.

SECTION II.—THE EARTH AND ELECTRICITY CONSIDERED AS SOURCES OF HEAT.

Q. How far BELOW the SURFACE of the EARTH does the influence of SOLAR HEAT extend ?

A. The depth varies from 50 *to* 100 *feet ;* never, however, exceeding the latter distance.

Q. How do we know that the EARTH is a SOURCE of HEAT ?

A. Because we find as we descend into the earth, and pass beyond the limit of solar heat, *that the temperature constantly increases.*

Q. At what RATE does the TEMPERATURE increase?

A. About *one degree* of the thermometer for *every fifty feet.*

Q. Supposing the temperature to continue to increase according to this ratio, what would be its effects at DIFFERENT DEPTHS?

A. At the depth of *two miles* water would be converted into steam; at *four miles*, tin would be melted; at *five miles*, lead; and at *thirty miles* almost every earthy substance would be reduced to a fluid state.

Q. To what CAUSE may EARTHQUAKES and VOLCANOES be attributed?

A. Undoubtedly to the agency of the *internal heat of the earth.*

Q. What effect has the INTERNAL HEAT OF THE EARTH on the TEMPERATURE of the SURFACE?

A. *No sensible effect:* it has been calculated that it affects the temperature of the surface less than $\frac{1}{30}$ of a degree of the thermometer.

Q. Why, if so great an amount of heat exists in the INTERIOR of the EARTH, does it not appear more manifest upon the SURFACE?

A. Because the materials of which the exterior strata or crust of the earth is composed *do not conduct* it to the surface from the interior.

Q. In what manner is ELECTRICITY a SOURCE of HEAT?

A. When an electric current passes from one substance to another, the substance which serves to conduct it is very frequently heated; but in what manner the heat is produced we have no positive information.

Q How GREAT a DEGREE of HEAT is ELECTRICITY capable of generating?

A. The *greatest known heat* with which we are acquainted is produced by the agency of the electric or galvanic current. All known substances can be melted or volatilised by it.

Q. Has the HEAT generated by ELECTRICITY been employed for any PRACTICAL or ECONOMICAL purposes?

A. *Not to any great extent;* but for philosophical experiments and investigations it has been made quite useful.

SECTION III.—CHEMICAL ACTION CONSIDERED AS A SOURCE OF HEAT.

Q. What is CHEMICAL ACTION?

A. We apply the term chemical action to those operations, whatever they may be, by which the *weight*, *form*, *solidity*, *colour*, *taste*, *smell*, and *action* of substances become changed; so that *new bodies*, with quite different properties, are formed from the *old.*

Q. How does CHEMICAL ACTION become a SOURCE of HEAT?

A. Many bodies, when their original constitution is altered, either by the abstraction of some of their component parts, or by the addition of other substances not before in combination with them, *evolve heat* while the change is taking place.

Q. Furnish an ILLUSTRATION.

A. Two *cold* liquids, as in the case of water and sulphuric acid, produce *intense heat*, if united.

Q. Why does COLD WATER poured on LIME make it intensely HOT ?

A. Because heat is evolved by the *chemical action* which takes place when the cold water combines with the lime.

Q. Did HEAT exist in the cold water and lime before they were mixed together ?

A. Yes, in a *latent* state.

Q. What do you mean by LATENT ?

A. *Latent*, from the Latin *lateo*, to lie hid, is something that is *not perceptible.* Latent heat is heat not felt ; such heat exists even in ice.

Q. Does cold iron contain HEAT ?

A. Yes ; *everything* contains heat ; but, when a thing *feels cold*, its heat is *latent.*

Q. What is meant by LATENT heat ?

A. Heat *not perceptible to our feelings.* When anything contains heat without *feeling* the hotter for it, that heat is called "*latent heat.*"

Q. Does COLD iron contain latent HEAT ?

A. Yes ; and when *the particles* are compressed by hammering, latent heat is brought out, and the iron becomes red hot.

Q. How are we made conscious of the EXISTENCE of heat, if we cannot feel it ?

A. By experiment ; thus the temperature of ice is 32°, but, if melted over a fire, 140° of heat being thereby absorbed, it will feel no hotter than before ; the 140° degrees of heat, being hidden, is in a latent condition.

Q. What AMOUNT of heat may thus exist in a latent condition ?

A. The quantity is variable ; 1,140° may be in this condition, as 140° of heat are latent when ice is melted by natural or artificial means, and 1,000° of heat are secreted when water is converted into steam, so ice converted into steam contains 1,140° of latent heat.

Q. By what simple experiment can we be made to feel the WARMTH of SNOW ?

A. Salt added to snow makes it so intensely cold, that, after plunging our hands into the mixture, snow appears comparatively warm.

Q. Why does STEAM burn so much more severely than BOILING WATER ?

A. Steam condenses as soon as it is exposed to the cold, and gives out all the *heat* by which it was produced ; therefore, as *one thousand degrees* of heat become latent in steam, it gives out that amount when condensed, which is much *greater* than boiling water.

Q. Why is the AIR in the SPRING, when the ICE and SNOW are melting, always very CHILLY and COLD ?

A. Solid bodies, in passing to the liquid state, *absorb heat* in large quantities ; when ice and snow are thawing, they absorb heat from the air, in consequence of which its temperature is greatly reduced.

Q. Why does the WEATHER always MODERATE on the FALL of SNOW ?

A. Bodies, in passing from the liquid to the solid state, *give out heat ;* snow is frozen water, and in its formation heat is imparted to the atmosphere, and its temperature increased.

Q. Why does the temperature of MELTING ICE and SNOW never exceed 32° ?

A. Because all the heat imparted to melting ice and snow *becomes insensible* until the liquefaction is complete.

Q. WHO originated the doctrine of LATENT HEAT ?

A. *Dr. Black*, of Edinburgh, during the last century.

Q. In WHAT MANNER was he led to his conclusions ?

A. He noticed that if a pound of water at 32° be mixed with a pound at 172°, the temperature of the mixture will be intermediate between them, or 102°. But if a pound of water at 172° be added to a pound of ice at 32°, the ice will quickly dissolve ; and, on placing a thermometer in the mixture, it will be found to stand not at 102°, but at 32°.

In this experiment he noticed, therefore, that the pound of hot water, which was originally at 172°, actually lost 140° of heat, all of which entered into the ice and caused its liquefaction, but did not affect its temperature. Hence it followed that a quantity of heat became insensible during the melting of the ice, sufficient to raise the temperature of an equal weight of water 140°.

Q. What CHANGES did Dr. BLACK suppose that the heat underwent during this transformation ?

A. He conceived that heat, in causing fluidity, *loses its property of acting on the thermometer* in consequence of *combining with the solid substance ;* and that liquefaction results because the compound so formed does not possess that degree of cohesive attraction on which solidity depends. When a liquid is cooled to a certain point, it parts with its heat of fluidity, which is set free or becomes sensible, and the cohesion natural to the solid is restored.

Q. Why do SALT and SNOW mixed together produce INTENSE COLD ?

A. The salt and snow are both solids, which, on being mixed, the salt causes the snow to melt by reason of its *attraction for water*, and the water formed dissolves the salt : so that both pass from the solid to the liquid condition, and a large quantity of heat is absorbed. This heat, being derived from that which previously existed in the solids themselves in a sensible state, causes the temperature necessarily to fall.

Q. How great a degree of cold can thus be generated by a mixture of salt and snow ?

A. About 32° below the temperature of freezing water.

Q. What are the COLDEST MIXTURES known ?

A. Three parts of muriate of lime, with one part of snow. Five parts of diluted sulphuric acid, with four parts of snow.

SECTION IV.—MECHANICAL ACTION CONSIDERED AS A SOURCE OF HEAT.

Q. How does MECHANICAL ACTION produce heat ?

A. By *percussion*, *friction*, and *condensation.*

Q. What is meant by PERCUSSION ?

A. The shock produced by the collision of two bodies.

Q. Why does STRIKING IRON make it RED HOT ?

A. It *condenses the particles* of the metal, and excites the latent heat.

Q. Why are SPARKS produced by striking with FLINT and STEEL ?

A. It disturbs the latent heat by compressing the particles of the bodies struck.

Q. How does the DISTURBANCE of this latent heat SET TINDER ON FIRE ?

A. A particle of red hot matter, either from the steel or flint, is struck off, and, falling on the tinder, sets fire to it.

Q. What occasion these particles being RED HOT ?

A. The latent heat is rendered sensible by condensation, and is made red hot in some of its particles.

Q. When the percussion of the flint and steel is made to occur in a VACUUM, what takes place ?

A. The heated particles are produced equally well as before, but are scarcely visible, from the absence of the atmosphere.

Q. What is FRICTION ?

A. Friction is the act of *rubbing two things together.*

Q. Cannot FIRE be produced by FRICTION ?

A. Yes; the Indians, for instance, take a flat piece of wood, and rub on it a sharpened, pointed piece, till a groove is made, and the dust catches fire, latent heat being evolved by friction.

Q. What SORT of WOOD is best adapted for this purpose ?

A. Poplar, ivy, laurel, boxwood, and mulberry.

Q. Does not friction sometimes occasion CARRIAGE WHEELS to TAKE FIRE ?

A. Yes; ignition being produced in consequence of the disturbance of latent heat.

Q. To WHAT is this attributable ?

A. It is owing to the wheels being too dry, too tightly fitted, or moving too rapidly.

Q. For what purpose are CART WHEELS GREASED ?

A. Grease *lessens the friction;* and, when there is *less friction*, the latent heat of the wheels is less disturbed.

Q. What EFFECT is produced by RUBBING our HANDS and FACES ?

A. They are made to feel warm, the latent heat being excited, and increased rapidity of circulation given to the blood. A person almost drowned is thus restored to animation.

Q. If pieces of ICE are RUBBED together, what is the result ?

A. They melt, latent heat being excited by friction.

Q. Furnish some other instances of the RESULTS of FRICTION.

A. Tools become hot by being used; the borers, in boring cannon, blister the hand. In all cases of this sort, latent heat is evolved by friction.

Q. What interesting experiment was made by COUNT RUMFORD, illustrative of the effect of friction in producing HEAT ?

A. A borer was made to revolve in a cylinder of brass, partially

bored, thirty-two times in a minute. The cylinder was enclosed in a box containing 18 pounds of water, the temperature of which was at first 60°, but rose in an hour to 107°; and in two hours and a half the water boiled.

Q. Is AIR necessary to the production of HEAT by FRICTION?

A. Air does not appear to be necessary to the production of heat by the attrition of solid bodies; *heat is produced by friction within a vacuum.*

Q. Does a BODY ever cease to give out HEAT by FRICTION?

A. No; however long the operation may be continued.

Q. What conclusions respecting the nature of heat have philosophers drawn from this fact?

A. That heat cannot be a *material substance*, but merely a *property of matter.*

Q. Is HEAT EVER produced by the FRICTION of LIQUIDS?

A. No; solids alone produce heat by friction; and no elevation of temperature takes place from the mere agitation of fluids with one another.

Q. Is the heat excited by friction in proportion to the HARDNESS or ELASTICITY of the bodies employed?

A. No; on the contrary, a piece of brass rubbed with a piece of cedar-wood produces more heat than when rubbed with another piece of metal; and the heat is still greater when two pieces of wood are employed.

Q. Why does the FULMINATING COMPOSITION of a PERCUSSION CAP explode when struck with a hammer?

A. Because the blow occasions compression of the particles, by which the latent heat is concentrated to such a degree as to cause an explosion.

Q. Why does a FRICTION MATCH, drawn over sand paper or other rough substance, ignite?

A. When the match is drawn over sand paper or other rough substance, certain phosphoric particles are rubbed off, and *being compressed* between the match and the paper, their heat is raised sufficiently high to ignite them, and fire the match. If the match be drawn over a *smooth* surface, the compression *must be increased*, for the temperature of the whole phosphoric mass must be raised in order to cause ignition.

Q. Why is it easier to produce HEAT from the friction of ROUGH SURFACES than SMOOTH ONES?

A. Because in the friction of rough surfaces certain particles *are rubbed off*, which *being small*, are *readily condensed*, and made to evolve their latent caloric.

Q. Why, when you rub a smooth METALLIC SURFACE, as a BUTTON for example, against a piece of plank, does the metal become more heated than the wood?

A. Because the caloric is *forced out of the wood*, as it were, by the compression of its parts, and the button receives most of the caloric, owing to a stronger attraction for it, than is possessed by the wood.

Q. What is COMPRESSION?

A. Compression is bringing various particles in closer contact.

Q. Is HEAT evolved by COMPRESSION?

A. Yes; even from common air. Thus a piece of German tinder, if placed at the bottom of a glass tube, and the air in the tube compressed, catches fire; the latent heat of the air being forced out, and thus setting fire to the tinder.

Q. Why does the HOLE made by a shot or cannon ball in a wall or timber, look as if it were BURNT?

A. Because the shot or cannon balls were so heated by the discharge, as actually to scorch the material into which they penetrated.

Q. Why are SHOT and CANNON BALLS HEATED by being discharged from a gun or cannon?

A. Because the air is so rapidly condensed, when the charge is made, that sufficient latent heat is developed to make the shot or balls hot.

SECTION V.—VITAL ACTION CONSIDERED AS A SOURCE OF HEAT.

Q. What SINGULAR PROPERTY have all living animal bodies?

A. The property of *maintaining* in themselves an *equable temperature*, whether surrounded by bodies that are hotter or colder than they are themselves.

Q. ILLUSTRATE this fact.

A. The sailors of the Arctic exploring expedition during the polar winter, while breathing air that froze mercury, still had in them the natural warmth of 98° Fahrenheit; and the inhabitants of India, where the same thermometer sometimes stands 115° in the shade, have their blood at no higher temperature.

Q. Do VEGETABLES possess in ANY DEGREE THIS PROPERTY of maintaining a constant temperature within their structure?

A. *Growing* or *fresh* vegetables have this property to a *certain extent.*

Q. What, then, is VITAL HEAT?

A. The heat generated or excited by the *organs* of a *living structure.*

Q. What is the cause of VITAL OR ANIMAL HEAT?

A. The cause of animal heat is not certainly known or determined; it is supposed to be due to *chemical action*, the result of *respiration* and *nervous excitation.*

Q. Has the power of animals to preserve a peculiar temperature any limits?

A. *Yes; intense cold suddenly coming upon a man* who has not sufficient protection, first causes a sensation of pain, and then brings on an almost irresistible sleepiness, which, if indulged in, proves fatal. A great excess of heat, also, cannot long be sustained by the human system.

Q. Does EACH SPECIES of animal appear to have a PECULIAR TEMPERATURE ?

A. Yes; each species of animal and vegetable appears to have a temperature *natural* and *peculiar* to itself, and from this diversity different races are fitted for different portions of the earth's surface.

Q. What EFFECT does the PECULIARITY of TEMPERATURE have upon the DISTRIBUTION and LOCATION of ANIMALS and PLANTS upon the earth's surface ?

A. The different species are confined and circumscribed within *certain districts*, depending mainly on their relations to heat. Thus, the orange-tree and the bird of paradise are confined to warm latitudes; the pine-tree and the Arctic bear, to those which are colder.

Q. What CURIOUS FACT in relation to a SPECIES of WHALE illustrates the influence of temperature in defining locations ?

A. It has been ascertained that at least one species of whale is precluded from migrating from the north to the south, from its inability to live in the heated waters of the equator.

Q. When animals or plants are removed from their peculiar and natural districts to one entirely different, WHAT CHANGES take place ?

A. They either *cease to exist*, or *change their character* in such a way as to adapt themselves to the climate.

Q. What CURIOUS ILLUSTRATIONS do we find of this ?

A. The *wool* of the northern sheep changes in the tropics to a species of *hair*. The *dog* of the torrid zone is nearly destitute of hair. *Bees* transported from the north to the region of perpetual summer *cease to lay up stores of honey*, and lose, in a great measure, their habits of industry.

Q. How has NATURE provided for the PROTECTION of ANIMALS against the modifications of temperature ?

A. By covering their bodies with a *form of fur*, *or hair*, *or feathers*, in the exact degree required, and to such an extent as to vary the covering in the same animal according to the climate and season.

Q. What ONE species of organised beings is fitted to live in ALL CLIMATES ?

A. *Man alone* is capable of living in all climates, and of migrating freely to all portions of the earth.

CHAPTER XV.

COMMUNICATION OF HEAT.

Q. In what THREE WAYS may HEAT be communicated ?

A. By *direct contact*, by *conduction* and *convection*, and by *radiation*.

Q. How may HEAT be communicated by CONTACT ?

A. When a hot body touches a cold one, the *heat passes directly* from one into the other, as when it enters a bar of iron put into the fire, or the hand immersed in hot water.

Q. When is HEAT communicated by CONDUCTION?

A. When the heat *travels from particle to particle* of the substance, as from the end of the iron bar placed in the fire to that part of the bar most remote from the fire.

Q. When is HEAT communicated by RADIATION?

A. When the heat *leaps*, as it were, from a hot to a cold body *through an appreciable interval of space*, as when a body is warmed by placing it before a fire removed to a little distance from it.

Q. In what way does a HEATED BODY COOL itself?

A. *First*, by giving off heat from its surface, either by *contact*, or *radiation*, or *both conjointly;* and, *secondly*, by the heat in its interior passing from particle to particle by *conduction* through its substance to the surface.

Q. In what MANNER does a COLD BODY become heated?

A. *First*, by heat passing into its surface either by *contact*, or *radiation*, or by *both conjointly;* and, *secondly*, by the heat at its surface passing from particle to particle through its interior portions *by conduction*.

Q. What are the PRINCIPAL CONDITIONS which influence the COMMUNICATION of heat from one body to another by contact?

A. The *degree of contiguity*, and the *conducting power* of the substances. The more perfect these relations, the more rapid the transfer.

Strictly speaking, the transfer of heat by direct contact is a case of radiation, in which the surfaces, though still separated by an interval, are at an insensible distance.

SECTION I.—CONDUCTION.

Q. Does HEAT pass through all bodies with the SAME VELOCITY?

A. *No;* some substances oppose very little impediment to its passage, while through others it is transmitted slowly.

Q. Into what TWO CLASSES are bodies divided in respect to their CONDUCTION of HEAT?

A. Into *conductors* and *non-conductors;* the former are such as allow heat to pass freely through them; the latter comprise those which do not give an easy passage to it.

Q. Are DENSE and SOLID BODIES the best CONDUCTORS of HEAT?

A. Yes; such as metals. Of these, gold, silver, and copper are the best, and lead the most inferior.

Q. Are LIGHT POROUS BODIES good CONDUCTORS?

A. No; hair, fur, wool, charcoal, are the worst conductors of heat known.

Q. On what principle do you account for SOME BODIES being COLDER than others?

A. Chiefly on account of their being better conductors, and drawing off heat from our bodies with greater rapidity than others.

Q. Why does a PIECE of WOOD blazing at ONE end NOT feel HOT at the OTHER?

A. Because *wood is so bad a conductor* that heat does not traverse

freely through it; hence, though one end of a stick be blazing, the other end may be quite cold.

Q. Why does a POKER resting on a fender feel COLDER than the HEARTH-RUG, which is farther off the fire?

A. Because the poker is an *excellent conductor*, and draws heat from the hand much *more rapidly* than the woollen hearth-rug, which is a very *bad conductor:* though both, therefore, are equally warm, the *poker* seems to be the *colder*.

Q. What is the CAUSE of IRON feeling so much COLDER than WOOD in winter?

A. Iron is a better conductor than wood, and produces the feeling of cold by drawing off the heat from our hand more rapidly than wood.

Q. Is the IRON really COLDER?

A. No; it possesses exactly the same amount of heat, if exposed to the same temperature.

Q. Why does a STONE PAVEMENT feel COLDER than a CARPETTED FLOOR, though exposed to the same temperature?

A. Because the stone is a better conductor than the carpet, and conveys heat away more rapidly from the human body.

Q. Does not the HEARTH-STONE feel WARMER than the HEARTH-RUG when the fire is kindled in the grate?

A. It does, being a better conductor, and giving forth heat more readily than the woollen rug.

Q. How does this account for its feeling WARM?

A. Heat is communicated to our bodies so rapidly by the stone, that we are made immediately sensible of the change.

Q. Why are WOODEN HANDLES put to METAL TEAPOTS?

A. Because wood, being a bad conductor, does not convey heat so rapidly as metal, and therefore makes it more convenient, as a handle, to be taken hold of: thus, while the metal is quite hot, the wooden handle remains comparatively cold.

Q. Is WOOLLEN CLOTH a BAD CONDUCTOR?

A. It is; and on this account we employ woollen kettle-holders, which prevent the rapid transmission of heat from the metal to our hands.

Q. Does a WOOLLEN KETTLE-HOLDER entirely prevent the transmission of HEAT?

A. No; but, being a bad conductor, it communicates heat too slowly to be felt, and never feels as hot, though, in reality, it may be as hot as the kettle itself.

Q. Is AIR or WATER the best CONDUCTOR of HEAT?

A. Water is a much better conductor than air, but no liquid is a good conductor.

Q. Furnish an ILLUSTRATION of this principle.

A. If we plunge any part of our body into cold water, it produces a sensation of cold, because it rapidly draws off the heat, and makes us feel the loss. Air abstracts heat, but more slowly, consequently less perceptibly.

Q. On what principle is WATER a better conductor than AIR?

A. The conducting power of any substance depends on the closeness of its particles, and water being denser than air, is, in consequence, a better conductor.

Q. Are LIQUIDS good conductors of HEAT?

A. No; heat in liquids produces evaporation, and flies off in vapour; water may boil at the surface, and leave ice unmelted a short distance below the surface.

Q. Is AIR a good CONDUCTOR?

A. No; *air* is a very *bad conductor.*

Q. How is a ROOM WARMED by a STOVE?

A. The air *nearest* the fire is made hot *first* and rises; *cold air* then *descends*, is heated, and *ascends* in like manner; and this interchange goes on till *all* the air of the room is *warmed.*

Q. If AIR be a BAD CONDUCTOR of heat, why should we not feel as warm WITHOUT clothing, as when we are wrapped in wool and fur?

A. Because the air *draws off* heat, and, by the ceaseless change of air, tends to decrease the warmth of that part of the body devoid of clothing. Thus, the air (which cases the body) absorbs as much heat from it as it can while it remains in contact; being then blown away, it makes room for a *fresh coat of air*, which absorbs *more* heat.

Q. Does the AIR surrounding a body unclothed become as WARM as the body itself?

A. The constant motion of the air prevents this: it would rise to the same heat if it remained without motion.

Q. What BENEFITS arise from AIR being a BAD CONDUCTOR?

A. If it were otherwise, and possessed as good conducting powers as metal or stone, the heat would be drawn off so rapidly from our bodies as to impede, if not destroy, animal and vegetable life.

Q. Why are WOOL and FUR used for clothing in COLD WEATHER? and do they IMPART HEAT?

A. Woollens and furs prevent the warmth of the body being drawn off, in consequence of being bad conductors. They prevent the escape of heat, but do not impart it.

Q. What is the CHIEF USE of CLOTHING in cold weather?

A. The prevention of the escape of animal heat, and the protection of the body from the cold air.

Q. How are these NECESSITIES answered in the condition of the lower animals?

A. Beasts are covered with fur, hair, or wool; birds with down or feathers.

Q. What PURPOSE do these answer?

A. Being bad conductors, they serve to keep them warm, preserving animal heat and protecting from the cold air. Birds, which are the most delicate, have a thicker covering of feathers. Beasts in the frigid zone have coarser and warmer coats than those in tropical regions.

Q. Why is moderately LOOSE clothing WARMER than that which fits TIGHTLY?

A. Because air is a *bad conductor;* and the quantity of air confined between our bodies and clothing prevents, 1. The heat of our bodies from *escaping;* and

2. The external air from coming into *contact* with our bodies. But if our clothing is sufficiently *loose* to admit of a *free circulation* of air, we shall feel *cold;* and, on the contrary, if it fits *very tightly*, it impedes the free circulation of the blood, and we feel *cold.*

Q. How are WHALES, SEALS, and other WARM-BLOODED ANIMALS that live in the water, protected against the cold?

A. They are enveloped, *beneath the skin*, with a thick coating of "*blubber*," or *fat*, which, like fur, hair, and feathers, is a non-conductor of heat, and serves to protect them in a like manner.

Q. Why are BLANKETS and WARM WOOLLEN GOODS always made with a NAP or PROJECTION OF FIBRES on the outside?

A. Because the *nap* or *fibres retain air* among them, which, from its non-conducting properties, serves to increase the warmth of the material.

Q. How does the COVERING of HAIR, WOOL, and FEATHERS, serve to keep animals COOL in HOT WEATHER, as well as WARM in COOL WEATHER?

A. In warm weather the *non-conducting medium* will not allow the heat to *enter* the body *from without;* in cold weather, the heat of the body *cannot escape from within.*

Q. Why do we wrap up ICE in FLANNEL to keep it from melting?

A. Because the flannel, being a *non-conductor*, does not allow the heat of the atmosphere to *penetrate* to the ice.

Q. Does not the bad conducting power of air enable persons to judge whether an EGG be NEW or STALE?

A. Yes; touch the larger end of the shell with your tongue; if it *feels warm*, the *egg is stale;* if *not*, it is new-laid.

Q. Why will the SHELL of a STALE EGG feel warm to the tongue?

A. Because the thick end of an egg contains *a small quantity of air* (between the shell and the white); when the egg is stale, the white *shrinks*, and the confined *air* accordingly *expands.*

Q. Why does the expansion of air (at the end of an egg) make it feel WARM to the tongue?

A. Because air is a very bad conductor; and the more *air* an egg contains, the *less heat will be drawn from the tongue* when it touches the shell.

Q. Why will a NEW-LAID egg feel COLDER to the tongue at the thick end than a stale one?

A. Because it contains *more white* and *less air;* and as the *white* of an egg is a better conductor than *air*, the heat of the tongue will be drawn off *more rapidly*, and the egg feel *colder.*

Q. Why are rooms much WARMER for being furnished with DOUBLE-DOORS and WINDOWS?

A. Because air is a *bad conductor;* and the air confined between

the double doors and windows opposes both the escape of *warm* air *out* of the room, and of *cold* air *into* the room.

Q. Why is a room WARMER when the WINDOW CURTAINS are drawn or the SHUTTERS shut?

A. Because air is a bad conductor; and the air confined between the curtains or shutters and the window, opposes both the escape of *warm* air *out* of the room, and of *cold* air *into* it. The curtains and the shutters also are non-conductors, and, at the same time, prevent the circulation of air and the existence of currents.

Q. Is LINEN a better conductor than COTTON?

A. Yes; therefore a linen shirt is much colder than a cotton one; and a cambric handkerchief cools the face, if wiped over it, far better than a cotton one.

Q. Is the SOIL a good conductor of HEAT?

A. No; its particles are not sufficiently close together, and density of matter is essential to conducting heat.

Q. Is the SOIL PENETRATED DEEPLY by the changes of SUMMER and WINTER?

A. No; being a bad conductor of heat, the soil below the surface is cool in summer and warm in winter.

Q. What BENEFITS arise from this?

A. If the soil was a good conductor, all vegetation would be destroyed; frozen in winter, and burnt up in summer.

Q. Is SNOW a GOOD CONDUCTOR of HEAT?

A. No; therefore in winter time it protects vegetables and seeds from the frosts; and the Bible says, "God giveth *snow* like *wool.*"

Q. How does SNOW protect VEGETATION from the FROST?

A. It prevents the heat of the ground being abstracted by the air.

Q. Why is SNOW a non-conductor of heat?

A. Principally because it contains a large quantity of *air* between its particles.

Q. Why is it COOL under a SHADY tree in a hot summer's day?

A. 1. Because the overhanging foliage *screens off the rays of the sun;*

2. As the rays of the sun are warded off, *the air* (beneath the tree) is not heated by the *reflection of the soil;* and

3. The leaves of the trees, being *non-conductors*, allow no heat to penetrate them.

Q. Why is the LID of a KETTLE intensely HOT when the water boils?

A. Because the bright metal lid is an *admirable conductor;* and therefore *the heat from the boiling water pours into our hand* the moment we touch it.

Q. Why are ICEHOUSES lined with STRAW, and generally WHITEWASHED on the outside?

A. 1. Because straw is a very bad conductor of heat, and therefore prevents the external heat from getting to the ice; and

2. The whitewashed roof and walls prevent the absorption of heat.

Q. Why will a little OIL on the surface of water prevent its FREEZING?

A. Because oil is a *bad conductor*, and prevents heat from leaving the water.

Q. A silver teaspoon becomes more heated by hot tea, than one of inferior metal (as German silver, pewter, &c.): why is this?

A. Because silver is a better *conductor* than German silver or pewter.

German silver is composed of twenty-five parts of nickel, twenty-five of zinc, and fifty of copper.

Pewter is, generally speaking, an alloy of tin and lead, sometimes with a little antimony or copper combined, in different proportions, according to the purposes for which it is designed.

Q. Why does a METAL SPOON (left in a saucepan) RETARD the process of BOILING?

A. Because the metal spoon (being an excellent *conductor*) *carries off the heat from the water*, and (as heat is carried off by the spoon) the water takes a longer time to boil.

Q. Why does PAINT preserve WOOD?

A. 1. Because it covers the surface of the wood, and prevents both air and damp from penetrating into the pores;

2. Because paint (especially white paint) being a *bad conductor*, preserves the wood of a more uniform temperature; and

3. Because it fills up the pores of the wood, prevents insects and vermin from harbouring therein and eating up the fibre.

Q. Are BRICKS good CONDUCTORS?

A. No; they prevent the escape of heat, and are consequently used for building stoves or furnaces, where much heat is required.

Q. Would a BRICK STOVE in the middle of a room make the room WARMER than an IRON one?

A. No; bricks would retain the heat—iron give it forth; the iron stove would therefore make the room much warmer than a brick one.

Q. Why do CELLARS feel WARM in WINTER?

A. Because the *external air* has not free access into them; in consequence of which they remain almost at an *even temperature*, which (in winter time) is about 10 degrees *warmer* than the external air.

Q. Why do CELLARS feel COLD in SUMMER?

A. Because the external air has not free access into them; in consequence of which they remain almost at an *even temperature*, which (in summer time) is about 10 degrees *colder* than the external air.

Q. In what respect is BARK especially adapted as a covering for trees and shrubs?

A. Bark is composed of matter which is *very slowly permeable by heat*, and, like hair and fur in animals, is especially adapted for securing the temperature necessary to vegetable life.

Q. What is the TEMPERATURE of the SAP of healthy trees during the SUMMER?

A. It is *several degrees below* that of the surrounding atmosphere.

Q. What is the TEMPERATURE of the SAP of a healthy tree in the WINTER?

A. *Several degrees* above that of the surrounding atmosphere.

Q. What occasions this DIFFERENCE between the temperature of the sap of a tree and the temperature of the surrounding atmosphere?

A. The *vital action* of the tree.

It is also a noticeable fact that sap drawn from a tree will freeze at the same temperature as water, while the sap circulating in the tree, under the influence of vital agency, will not freeze until reduced *seventeen degrees below* the freezing-point of water.

Q. Why in a frozen pond or lake is the ice always THINNER, and often ENTIRELY WANTING, in those parts where springs exist upon the bottom?

A. Because the spring water, coming from a point in the earth *below* the influence of the frosts, is *elevated* in temperature, and by *imparting its heat* prevents an accumulation of ice upon the surface above.

Q. Is there in reality any POSITIVE WARMTH in the materials of clothing?

A. No; but we consider clothing warm or cool according as it *impedes* or *facilitates* the passage of heat to or from the surface of our bodies. The thick cloak which guards a Spaniard against the cold of winter, is also in summer used by him as a protection against the direct rays of the sun; and, while in temperate climates flannel is the warmest article of dress, we cannot at the same time preserve ice more effectually than by enclosing it in its softest folds.

Q. Are FINE or COARSE woollens the WARMEST?

A. Fine woollens are warmer than coarse ones, because the finer the cloth, the more slowly it conducts heat.

Q. Is SILK a bad conductor of heat?

A. Yes, as it allows the heat of the body to pass off more rapidly than wool.

Q. The SHEETS of a bed feel COLD and the BLANKETS WARM: is there any difference in the respective temperature of these articles?

A. No; the temperature of both the sheets and the blankets is *always exactly the same.*

Q. Why, then, does one feel COLDER than the other?

A. Sheets feel colder than the blankets because they are *better conductors of heat*, and carry off the heat more rapidly from the body; but when by the continuance of the body between them they acquire the same temperature, they will then feel even *warmer* than the blankets.

Q. In the summer a still, CALM ATMOSPHERE feels warm, but if a wind arises, the same atmosphere feels cold: has there been any real CHANGE of temperature?

A. No; for a thermometer suspended *under shelter* and in a *calm place* will indicate the *same temperature* as a thermometer on which the wind blows.

Q. Why do we then consider that the AIR has grown COLDER?

A. Because the air in motion by the wind *conducts off* the heat from our bodies *faster* than the same air at rest.

SECTION II.—CONVECTION.

Q. What is CONVECTION of HEAT?

A. Convection of heat is that by which heat is *conveyed* to some other thing or place. Thus, the lower particles of water in a vessel being heated by a spirit lamp gradually ascend, conveying heat to other parts of the water.

Q. Are LIQUIDS good CONDUCTORS of heat?

A. No; liquids are bad *conductors*, and are therefore made hot by *convection*.

Q. Why are LIQUIDS BAD CONDUCTORS of heat?

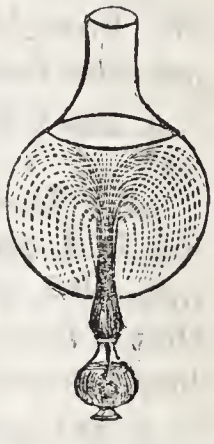
A. This peculiarity is referable to the *mobility* which subsists among the particles of *all fluids*, and to the change of *size* which is invariably produced by a change in temperature.

The constituent particles of solid bodies being incapable of changing their material position and arrangement, the heat can only pass through them from particle to particle, by a slow process; but when the particles forming any stratum of liquid are heated, their mass, expanding, becomes lighter, bulk for bulk, than the colder stratum immediately above it, and ascends, allowing the superior strata to descend.

Q. Explain how WATER is made HOT.

A. When the heat enters at the bottom of a vessel containing water, a *double set of currents* is immediately established,—one of *hot* particles *rising* towards the *surface*, and the other of *colder* particles *descending* to the *bottom*. The portion of liquid which receives heat from below is thus continually mixed through the other parts, and the heat is diffused by the motion of the particles among each other.

Fig. 53.



These currents take place so rapidly, that if a thermometer be placed at the bottom and another at the top of a long jar, the fire being applied below, the upper one will begin to rise almost as soon as the lower one. The movement of the particles of water in boiling will be understood by reference to *fig.* 53.

Q. What would be the EFFECT if the heat were applied to the TOP instead of the BOTTOM of a kettle containing liquid?

A. The particles of the liquid would maintain their *mutual arrangement*, and the transmission of heat would take place in the same manner as if the liquid were *solid*.

The heat is, in fact, conducted through the liquid. In this manner liquids have been shown to have very low conducting powers—so low, that for a long period they were supposed to be incapable of conducting heat.

Q. What EXPERIMENT shows the inferior conducting power of liquids?

A. If a small quantity of *alcohol* be poured on the surface of water at 32° Fahrenheit, and *inflamed*, it will *burn on the water*. A

thermometer, immersed at a small depth below the common surface of the spirit and the water, will, after a considerable lapse of time, *fail to show any increase in temperature.*

Q. Furnish another ILLUSTRATION of this principle.

A. If a bar of *red hot* iron be plunged into *cold* water, that part of the fluid which is *immediately around* the iron becomes *boiling hot*, the rest remaining *cold* as before.

Fig. 54.

If a tube nearly filled with water is held over a spirit lamp, as in *fig.* 54, in such a manner as to direct the flame against the upper layers of the water, the water will be observed to boil at the top, but remain cool below. If quicksilver, on the contrary, be so treated, its lower layers will speedily become heated. The particles of mercury will communicate the heat to each other, but the particles of water will not do so.

Q. Why is BOILING WATER always in a state of COMMOTION ?

A. The currents of hot and cold water *rising* and *falling*, together with the *escape of steam*, produce this effect.

Q. In what way do these ASCENDING and DESCENDING CURRENTS of water act ?

A. The *heated* water rises through the *centre*, and the *cold* water rapidly descends at the *sides.*

Q. Is it the property of HEATED water to ascend to the surface ?

A. Yes ; and therefore if heat were applied to the *top* of a kettle, and not to the *bottom*, the water would never be made to boil.

Q. What is the best way of COOLING liquids ?

A. By applying *cold* to the *top* of the liquid.

Q. On what principle ?

A. The cold portions *descend*, and as the warmer ones *ascend*, they are brought into contact with the cooling substance, and their *temperature lowered* in consequence.

Q. How is it, then, that a fire lighted in a grate makes the BOTTOM of the stove red-hot ?

A. The difference results from the difference of *substance.* Water is a bad, and iron an excellent conductor ; water conveys heat with difficulty, metal readily ; water will not diffuse heat in the same way that is done by heated metal ; in iron, when one part is heated, the heat is conducted to every part.

Q. If heat be applied to boiling water, is its TEMPERATURE INCREASED ?

A. No, not if it be possible for *steam* to escape ; the additional heat being carried away by the vapour of steam, and the water still remaining at boiling point.

Q. To what TEMPERATURE can water exposed to the AIR be heated under ordinary circumstances ?

A. To about 212° Fahrenheit ; at this temperature water passes into steam or vapour.

Q. Can water be heated BEYOND 212° ?

A. Yes ; if subjected to *sufficient pressure*, it can be heated to *any extent* without boiling. There is no limit to the degree to which

water may be heated, provided the vessel is strong enough to confine the vapour; but the expansive force of steam is so enormous under these circumstances, as to overcome the greatest resistance which has ever been exerted upon it.

Q. On what principle does SOUP, or BROTH, or WATER, thickened with starch or flour, keep HOT LONGER than plain water?

A. The grease in soup or broth holds the heat for a longer time than plain water; while starch, flour, or any thickening substance, impede the ascending motion of the heated water, and thus retard the escape of heat.

Q. How is AIR heated?

A. By convective currents; that is to say, the air is heated as water is heated, one portion having received a certain portion of heat rising to give place to colder, which, in its turn, is heated, and ascends.

Q. What is the meaning of the word CONVECTIVE?

A. It is derived from the Latin *cum vectus*, carried with; and is employed to describe this branch of natural philosophy, because the heat is carried with the current.

Q. Do the RAYS of the SUN impart HEAT to the air through which they pass?

A. Not to any very great extent. They heat the soil, which communicates to the air the heat it has received; and thus the air is hotter on a sunny than a sunless day.

Q. Does HEATED METAL grow COLD by exposure to the air?

A. Yes; both by radiation and convection.

Q. How by RADIATION?

A. By giving forth in rays the heat it has received.

Q. How by CONVECTION?

A. By the air which rests on the iron being heated gradually ascending, its place supplied by cold air, which, in its turn, carries off more heat; and so on till the iron is cold.

Q. Is a liquid COOLED by being AGITATED or STIRRED ABOUT?

A. Yes. Thus the stirring of hot tea brings to the surface more rapidly the hottest particles, thus bringing them in contact with the air, and producing convection with much greater rapidity than would have been the case had the liquid remained quiescent.

Q. How does BLOWING HOT FOOD make it COOL?

A. It causes the air (which has been heated by the food) to *change more rapidly*, and give place to fresh *cold air*.

Q. If a shutter be closed in the daytime, the stream of light (piercing through the crevice) seems in CONSTANT AGITATION: WHY is this?

A. Because little *motes* and *particles of dust* (thrown into agitation by the violence of the *convective currents*) are made *visible* by the strong beam of light thrown into the room through the crevice of the shutter.

Q. When POTATOES are boiled, why are those at the TOP of the boiler COOKED SOONER than those nearer the fire?

A. 1. Because the *hottest* particles of the water rise to the *top* of the boiler, and the *coldest* particles sink to the bottom; and

2. Because the top of the boiler is always enveloped with very hot escaping steam; in consequence of which the potatoes on the top are subjected to more intense heat than those at the bottom of the boiler.

Q. Why does MILK BOIL more QUICKLY than water?

A. Milk is a *thicker* liquid than water, and, consequently, *less steam* escapes through the thick liquid (milk) than through the thin liquid (water); therefore the heat of the whole mass of the milk rises more quickly.

Q. On what philosophical principle is an APARTMENT warmed by a STOVE?

A. The heat of the stove communicates itself to the surrounding air, which gradually rises, giving place to cold air, which is, in like manner, heated, and ascends. Warmth is thus, by degrees, caused all over the room. As heated air always ascends, the lower the position of a stove, the better adapted is it for effectually heating a room.

Q. Would not the air of the lower part of a room be heated equally well if the fires were fixed higher up?

A. No; the heat of a fire has very little effect upon the air *below the level of the fire;* and therefore every fire should be as *near to the floor* as possible.

Q. Our FEET are very frequently COLD when we sit close by a good fire: explain the reason of this.

A. As the fire consumes the air which passes over it, *cold air* rushes through the crevices of the doors and windows, and *along the bottom of the room*, to supply the deficiency; and these currents of cold air *rushing constantly over our feet*, deprive them of their warmth.

Q. According to the foregoing illustrations, upon what does the POWER of liquids to conduct heat DEPEND?

A. Upon the *mobility* of their particles, as their power to diffuse heat depends on their power of *carrying*, and not of *conducting*, it.

Any circumstances which impede the motion of the fluid particles among themselves diminish the diffusing power of the liquid.

Q. Why will SPIRITS boil more quickly than WATER?

A. Because the particles of the spirits are *more free to move and conduct heat* than the particles of water.

Q. Why does it require a higher temperature to boil oil, molasses, or syrups, than water?

A. Because the oil, molasses, &c., are *viscid* fluids, and the particles do *not* move freely among themselves.

Q. Is the process of COOLING in liquids influenced by the same law that regulates their BOILING temperature?

A. Yes; cooling being merely the reverse of *heating;* those liquids cool quickest whose particles have the *greatest freedom of*

motion. Hence, all semifluid masses, such as tar, molasses, thin mush, &c., retain their heat for a great length of time.

Q. How does the same law explain the fact that very POROUS MASSES and powders, as charcoal, metal filings, sawdust, sand, &c., conduct heat more SLOWLY than denser masses?

A. Because their interstices are *filled with air*, which scarcely conducts heat, and which, by the structure of the substance, has *no freedom of motion or circulation* by which it might carry away the heat.

SECTION III.—RADIATION.

Q. What is meant by RADIATION of HEAT?

A. The *emission* of rays of heat in *all directions*.

When the hand is placed near a hot body suspended in the air, a sensation of warmth is perceived, even for a considerable distance. If the hand be held beneath the body, the sensation will be as great as upon the sides, although the heat has to shoot down through an opposing current of air approaching it. This effect does not arise from the heat being conveyed by means of a hot current, since all the heated particles have a uniform tendency to rise; neither can it depend upon the conducting power of the air, because aerial substances possess that power in a very low degree, while the sensation in the present case is excited almost on the instant. This method of distributing heat, to distinguish it from heat passing by contact or conduction, is called *radiation*.

Q. How do we designate HEAT so distributed?

A. As *radiant* or *radiated* heat.

Q. On what is RADIATION dependent?

A. On unevenness of surface, as in proportion to the number of points from which heat can escape, is the power of radiation increased.

Q. Is heat radiated from BURNING FUEL?

A. Yes; we feel hot on standing near a fire.

Q. Do not the FACE and HANDS feel the heat more than the rest of the body?

A. The face and hands being generally uncovered, the heat is felt by them more readily; clothing, being in most cases a bad conductor, prevents the rapid transmission of heat to other parts of the skin.

Q. Are ABSORPTION and RADIATION of heat in any way CONNECTED?

A. Substances which radiate the most heat, absorb the most heat; and those which radiate the least, absorb the least.

Q. What OTHER SUBSTANCES beside the SUN and BURNING FUEL radiate heat?

A. Nearly all dull and dark substances are excellent radiators of heat.

The action of a blackened surface of tin being assumed as 100, it has been found that that of a *steel* plate was 15; of *clean tin*, 12; of tin *scraped bright*, 16; when scraped with the edge of a *fine file in one direction*, 26; when scraped again *across*, about 13; a surface of *clean lead*, 19; covered with a *gray crust*, 45; a thin crust of *isinglass*, 80; *resin*, 96; *writing paper*, 98; *ice*, 85.

Q. What is meant by being a "bad RADIATOR of heat?"

A. To radiate heat is to *throw off heat by rays*, as the sun; a polished tin pan does *not throw off the heat of boiling water* from its surface, but *keeps it in*.

Q. Why is a TIN BOX (filled with HOT WATER) employed as a FOOT-WARMER ?

A. Because *polished tin* (being a bad radiator of heat) *keeps hot a very long time*, and warms the feet resting upon it.

Q. Why would the tin foot-warmer get COLD SOONER if the POLISH were INJURED ?

A. Because *polished* tin throws off its heat *very slowly;* but dull, scratched, painted, or dirty tin, *throws off its heat very quickly.*

Q. Why are TIN FOOT-WARMERS generally covered with FLANNEL ?

A. 1. That the *polish* of the tin may not be injured;

2. Because the flannel (being a *very bad conductor*) serves to keep the tin hot *longer;* and

3. Lest the conducting surface of the tin should *feel painfully hot.*

Q. Why does SNOW (at the foot of a TREE or WALL) melt sooner than that in an open place ?

A. Because the tree or wall melts the snow by *radiating heat into it from beneath.*

Q. How is hot iron cooled by RADIATION ?

A. While its heat is being carried off by "convection," the hot iron *throws off heat* (on all sides) *by radiation* also.

Q. Why should BLACK LEAD be employed to blacken the FLUES connected with stoves ?

A. As black lead radiates heat most freely, the heat is thereby diffused more equally and more rapidly through the room.

Q. Is a DULL, BLACK TEAPOT, or a BRIGHT METAL TEAPOT, the best for making TEA ?

A. The brightly polished metal, which, being a very bad radiator of heat, keeps the water hot much longer.

Q. Why is boiling water KEPT HOT in a BRIGHT METAL pot better than in an earthen vessel ?

A. Because bright metal (being a *bad radiator*) will not *throw off from its surface* the heat of the boiling water.

Q. What is the DIFFERENCE in degrees in the radiating powers of a black stone-ware teapot, and a polished metal one ?

A. The earthen teapot will radiate *one hundred degrees* of its heat in the same manner that the pot of polished metal will radiate only *twelve degrees.*

Q. Are bright DISH-COVERS serviceable on the same account ?

A. Yes; being bad conductors of heat, they prevent its escape, and thereby keep the cooked victuals hot much longer than would be possible without.

Q. What would be the result if these MEAT-COVERS were left DULL or SCRATCHED ?

A. It would produce entirely the contrary effect from that which was intended, making the food cold instead of keeping it hot, by absorbing heat from the smoking victuals.

Q. Why should a SILVER MEAT-COVER be PLAIN, and not CHASED ?

A. Because a *chased* meat cover would *radiate heat derived from the food;* and (instead of *keeping it hot*) *make it cold.*

Q. How could CHASING produce this effect ?

A. Chasing makes the surface *rough*, and rough surfaces *throw off the heat* most readily.

Q. Has COLOUR any influence upon the radiating power of a surface?

A. It has generally been supposed to have a very sensible influence, but recent experiments have furnished conclusive proof that *colour alone has no influence.*

Q. Of what NATURE is the heat received from the sun?

A. It is all *radiant heat.*

Q. How does the heat radiated by the sun DIFFER from other radiant heat?

A. The heat of the sun passes through *air*, *glass*, *water*, and *transparent bodies* generally *very readily*, while other radiant heat, though not obstructed by air, is *almost totally intercepted* or *absorbed* in passing through any of the various substances named.

Q. Is it necessary that there should be some MEDIUM of communication in order that heat shall be radiated from one body to another?

A. From the fact that radiant heat passes freely through a vacuum, it is inferred that the presence of a medium is *not necessary* to its passage.

Q. What TWO THEORIES have been proposed to account for radiation?

A. Those of *Pictet* and *Prevost*, two eminent French philosophers.

Q. What is the THEORY of Pictet?

A. It supposes that bodies of *equal temperature do not radiate* at all; and when the temperature is unequal, the hotter gives calorific rays to colder bodies, till an equilibrium is established, at which moment the radiation ceases.

Q. What is the THEORY of Prevost?

A. It supposes that radiation goes on at *all times and from all substances*, whether their temperature be the same or different from that of surrounding objects: therefore the temperature of a body falls when it radiates more heat than it absorbs; its temperature is stationary when the quantities emitted and received are equal; and it grows warm when the absorption exceeds the radiation. Of the two theories, that of Prevost is most generally adopted.

CHAPTER XVI.

PHENOMENA AND PRODUCTION OF DEW.

Q. What is DEW?

A. A watery vapour, which floating in the air is condensed into drops during the night.

Q. By what means is it CONDENSED?

A. By coming into immediate contact with bodies colder than itself.

Q. Does this account for the ground being COVERED with DEW?

A. It does: in the evening the earth is made so cold by radiation, that the warm vapours of the air are chilled and condensed into dew.

Q. How do you account for the EARTH being colder than the AIR after sunset?

A. On the principle that the air radiates less freely than the earth; thus the earth is colder than the air after sunset, though it may have been warmer than the air throughout the day.

Q. Why is the EARTH warmer than the AIR?

A. The earth absorbs the sun's rays, by which it is warmed; but the sun's rays pass through the air without effecting any perceptible difference in its temperature.

Q. When does the most DEW fall?

A. On calm and serene nights.

Q. On what principle do you account for this?

A. On a fine night the ground radiates more heat, and, being thus cooled, chills the vapour into dew; on a cloudy, murky night, the heat not escaping from the earth, the vapour in the air is not chilled, and consequently there is no dew.

Q. How do clouds ARREST or PREVENT the radiation of heat from the earth?

A. The lower surfaces of the clouds *turn back* the rays of heat as they radiate or pass off from the earth, and prevent their dispersion into space.

Q. What is RAIN?

A. Rain is water taken up into the atmosphere in the form of vapour, and returned to the earth in liquid drops.

Q. What is the difference between RAIN and DEW?

A. Dew is condensed vapour on the surface of the ground; rain, liquid drops falling from a height.

Q. What is the cause of both DEW and RAIN?

A. The condensation of vapour in the air.

Q. Why does ABUNDANCE of DEW in the morning indicate that the day will be FINE?

A. Because dew is never deposited in *dull*, *cloudy* weather, but only in very *clear*, *calm* nights, when the cold currents of air are not mixed with those of a warmer temperature.

Q. When is DEW the most abundant?

A. In situations the most exposed. Thus, there is more dew in the country than the town; and thus, too, there is scarcely any dew to be found under a leafy tree.

Q. How is this to be accounted for?

A. Because any shelter arrests radiation from the earth, and prevents the surface cooling down sufficiently to chill the vapour into dew.

Q. Why, in travelling, do we experience less dust in the NIGHT-TIME than during the day?

A. 1. Because the *dews* of night moisten the dust, and prevent its rising into the air; and

2. As the surface of the earth is colder than the air after sunset, the currents of the wind will incline *downwards*, and tend rather to press the dust down than to buoy it up.

Q. Why, on a WINDY NIGHT, is there NO DEW?

A. Because the wind *disturbs* the radiation of heat, and thus diminishes the deposition of dew, and *evaporates* the moisture as fast as it is deposited.

Q. Why are substances which radiate the heat MOST FREELY always the most THICKLY COVERED with DEW?

A. Because they are the coldest substances, and therefore condense vapour most readily.

Q. Are SOME bodies covered with DEW SOONER than OTHERS?

A. Yes; because they are much cooler during the night, in consequence of radiating heat more freely.

Q. What circumstances favour the FORMATION of DEW?

A. All circumstances that favour *radiation* equally contribute to the formation of dew. Any substance which is a good radiator will consequently be covered with dew.

Q. What bodies RADIATE HEAT most FREELY?

A. Glass more than the metals; grass, wood, and vegetation generally radiate freely.

Q. Do ALL plants radiate EQUALLY WELL?

A. No; the holly-hock radiates better than the laurel.

Q. What BENEFICIAL RESULTS ensue from this RADIATORY POWER of plants?

A. They receive thereby the moisture which is so essential to them, for by radiating heat they chill the vapours in the air, and convert them into dew.

Q. Then all substances SIMILARLY EXPOSED to the fall of DEW are not EQUALLY AFFECTED?

A. No; they receive dew in proportion as they radiate heat. Thus, while a grass plot may be thick with dew, a gravel-walk, a piece of polished metal, or woollen cloth, may be almost dry.

Q. Does the fall of DEW depend ALONE on the RADIATING POWER of the EARTH?

A. No; it also depends on the amount of vapour in the atmosphere.

Q. What does a HEAVY FALL of DEW INDICATE?

A. It may be considered as a prognostic of rain, as it shows us the quantity of aqueous vapour which is in the air.

Q. Where does MOST DEW fall?

A. More dew falls on cultivated soils than on barren lands, as the loose, porous earth of cultivated soils radiates more freely, and condenses the vapour more rapidly.

Q. Why do our CLOTHES generally FEEL DAMP after walking in a fine evening in SPRING or AUTUMN?

A. Because the vapour (condensed by the cold earth) lights upon them like dew.

Q. When is DEW most COPIOUSLY distilled?

A. After a hot day in summer or autumn, especially if the *wind* blows over a body of water.

Q. Why is DEW distilled most COPIOUSLY after a HOT day?

A. Because the surface of the hot earth *radiates* heat very freely at sunset, and (being made much colder than the air) chills the passing vapour, and condenses it into dew.

Q. Why is there LESS DEW when the WIND blows across the LAND than when it blows over a body of WATER?

A. Because the winds which blow across the *land* are dry and arid; but those which cross the *water* are moist and full of vapour.

Q. How does the DRYNESS of the wind PREVENT DEW-FALLS?

A. As winds (currents of air) which blow over the land are very dry, they imbibe the moisture of the air; in consequence of which there is *very little* left to be condensed into dew.

Q. How does the MOISTURE of the wind PROMOTE dew-falls?

A. As winds which blow over water are *saturated* with vapour, they require very little *reduction* of heat to cause a *copious* deposition of dew.

Q. Does not AIR radiate heat, as well as the EARTH and its various plants?

A. No; the air never radiates heat; nor is the air made *hot* by the rays of the sun.

Q. Is the DEW of EVENING INJURIOUS to HEALTH?

Yes; being laden with *noxious* vapours from the earth.

Q. Why is MEAT very subject to TAINT on a MOONLIGHT night?

A. Because it *radiates* heat very freely in a bright moonlight night; in consequence of which it is soon covered with *dew*, which produces rapid decomposition.

Q. Why is the air in immediate contact with the earth, on a clear night, cooler than the air at a little distance from the surface?

A. Because it parts with its heat to the earth, which in turn loses it by radiation.

Q. Why are shrubs and low plants more liable to be frost-bitten than trees?

A. Because they do not rise far above the surface of the earth; and (as the air contiguous to the earth is colder than the air which is more elevated) therefore the low vegetation is often frost-bitten, when the foliage of high trees escapes uninjured.

Q. How can a thin covering even of MUSLIN protect trees from FROST?

A. Because any covering prevents the radiation of heat from the tree; and if trees are not cooled down by radiation, the vapour of the air will not be frozen as it comes in contact with them. For this purpose matting is used by gardeners.

Q. Why is the BASS or CANVASS itself (which covers the tree) always DRENCHED with DEW?

A. Because it *radiates heat* both upwards and downwards; in consequence of which it is so cooled down that it readily chills the vapour of the air into dew.

Q. Why is there LESS DEW when the WIND is EASTERLY than when the wind is WESTERLY?

A. Because *easterly* winds cross the continent, and (as they pass

over land) are dry and arid; but *westerly winds* cross the *Atlantic Ocean*, and (as they pass over water) are moist and full of vapour.

Q. How does the DRYNESS of an easterly wind PREVENT DEW-FALLS?

A. As easterly winds are very dry, they imbibe the moisture of the air; in consequence of which, there is very little left to be condensed into *dew*.

Q. How does the DAMPNESS of a westerly wind PROMOTE deposition of dew?

A. As westerly winds are *saturated* with vapour, they require very little reduction of heat to cause a copious deposition of dew.

Q. By what is MIST occasioned?

A. Mist, or earth fog, as it is sometimes called, is the condensed vapour of the air, chilled with greater rapidity than can possibly be deposited in the dew, and which, consequently, settles down on the earth as a fog or mist.

Q. This MIST seems to RISE HIGHER and HIGHER, and yet remains quite as dense below as at first: explain the cause of this.

A. The air resting on the *earth* is first chilled, and chills the air resting on it; the air which touches this new layer of mist being also condensed, layer is added to layer; and thus the mist seems to be *rising*, when (in fact) it is only *deepening*.

Q. Can the dew properly be said to "FALL?"

A. No; dew is always *formed upon the surface* of the material upon which it is found, and does not fall from the atmosphere.

Q. Does the COLOUR of an object influence the deposition of dew?

A. It does to *a considerable extent*.

Q. How can this be shown?

A. If we take pieces of red, black, green, and yellow glass, and expose them when the dew is condensing, we shall find that moisture will show itself first on the *yellow*, and then on the *green* glass, but that none will appear on the *red* or *black* glass. The same thing will take place if we expose coloured fluids in white glass bottles.

Q. Is the cause of this phenomenon UNDERSTOOD?

A. It is *not*.

It is not explicable upon the idea of difference in mechanical arrangement, as it is quite independent of surface condition.

Q. In a clear summer night, when dew is depositing, what is generally the DIFFERENCE of TEMPERATURE between a plat of grass and the air at some distance above it?

A. A thermometer laid upon the grass will sink nearly *twenty* degrees below one suspended in the air at some height above.

Q. Why is the deposition of dew rarely observed in the close and sheltered STREETS of CITIES?

A. Because there the objects are necessarily exposed to each other's radiation, and an interchange of heat takes place, which maintains them at a temperature uniform with the air.

Q. What do we mean when we speak of the "DEW-POINT?"

A. It is the *degree* indicated by the thermometer when dew *begins* to be deposited.

Q. Is this point a CONSTANT OR INVARIABLE one?

A. No; dew is only deposited when the air is *saturated* with vapour, and the amount of moisture required to saturate air of high temperature, is much greater than air of low temperature.

Consequently, air, which contains moisture to its utmost capacity at a given temperature, must necessarily deposit some of it when its temperature is diminished.

Q. When will there be the GREATEST, and when the LEAST, difference between the temperature of the air and the dew-point?

A. If the saturation be *complete*, the least diminution of temperature is attended with the formation of dew; but if the air is *dry*, a body must be several degrees *colder* before moisture is deposited on its surface; and, indeed, the drier the atmosphere, the greater will be the difference between the temperature and its dew-point.

Q. How can we cause the production of dew in the DAYTIME at any season?

A. By bringing a tumbler of *cold* water into a *warm* room.

Q. How does this cause the production of dew?

A. The tumbler of water cools the air contiguous to it below the dew-point, and dew consequently forms upon it.

Q. When is dew converted into frost?

A. If the temperature of the earth, or of the vessel, sink to the freezing point or below, the moisture will be deposited as before; but by freezing, it assumes the solid form, and is called frost.

Q. What occasions the ROUNDNESS of a DEW-DROP?

A. Every particle in the drop being equally balanced.

Q. Are not DEW-DROPS FLATTENED?

A. Yes; but this arises when two or more drops commingle, and so make one flattened drop.

Q. What is such a dew-drop CALLED?

A. A *spheroid.*

Q. Why is it that certain species of vegetation, as CABBAGE-PLANTS, POPPIES, and the PETALS of a ROSE, REPEL WET?

A. On account of their possessing some peculiar property which repels wet; the fine waxen powder of the cabbage-plant, and the volatile oil of the rose, answer this purpose. On the same principle, aquatic birds dive under water without being wetted, on account of the oily secretion which covers their feathers.

Q. What is the FIGURE which water always assumes when unsupported, or supported on a surface having little attraction for it?

A. The figure of a *sphere.* This figure becomes more or less globular or spheroidal in its shape, as the attraction of the substances upon which it is received increases or diminishes.

Q. What is the FORM of a drop of rain when descending in the air?

A. A *sphere.*

Q. Why should drops of water, resting upon surfaces which have no AFFINITY for them, assume a spheroidal shape?

A. Because such surfaces not having so great an attraction for the drops of water as the particles of water have for each other, the drops tend to preserve, as nearly as possible, the *spheroidal form* which they would have if entirely unsupported, as when falling as drops of rain.

Q. Is dew ever formed upon the SURFACE of water?

A. The formation of dew upon ships which traverse the vast solitudes of the ocean has never been noticed; and it has been ascertained by experiment that even a small quantity of water gains no weight by exposure during a single night.

Although dew does not appear upon ships at a great distance from land, it is freely deposited on the same vessels arriving in the vicinity of *terra firma.* Thus, navigators who proceed from the Straits of Sunda to the Coromandel coast, know that they are near the end of the voyage when they perceive the ropes, sails, and other objects placed on the deck, become moistened with dew during the night.

Q. Why does not dew form upon the SURFACE of WATER?

A. Because whenever the aqueous particles of the surface are cooled, they become heavier than those below them, and sink, while warmer and lighter particles rise to the top. These, in their turn, become heavier, and descend; and the process, continuing throughout the night, maintains the surface of the water and the air at nearly the same temperature.

Q. Does dew deposit upon SHIPS at sea?

A. It appears, from the observations made by the United States Exploring Expedition, and from other sources, that on the ocean *heavy deposits of dew* sometimes occur upon the decks of vessels.

Q. Why are the EXPOSED PARTS of the human body never covered with dew?

A. Because the *vital heat*, varying from 96° to 98° Fahrenheit, effectually *prevents* such a loss of warmth as is necessary to its production.

Q. Why is dew more abundant in the EARLY part of AUTUMN than at any other period?

A. The days being then *warm*, the nights *cold*, and the *vapour* in the air *plentiful*, the same degree of cold condenses a greater quantity of vapour than at any other period.

Q. In what COUNTRIES are the dews most copious and abundant?

A. In *tropical* climates.

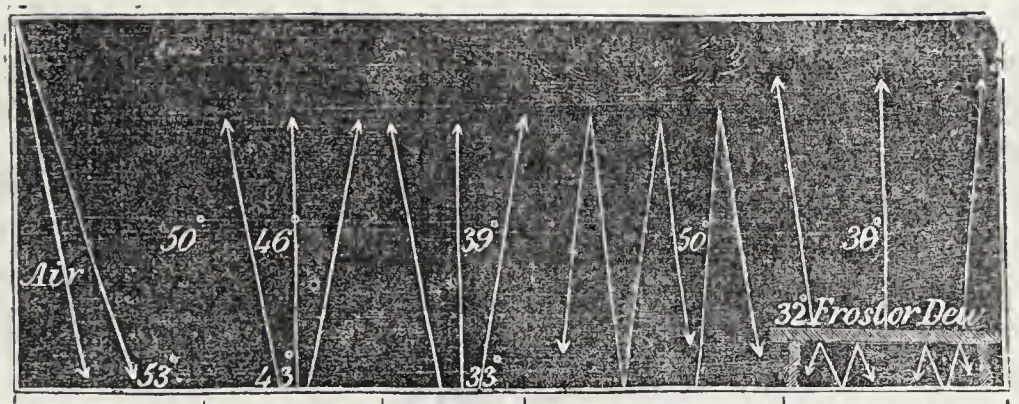
Q. What is the REASON of this?

A. Because in those countries there is the greatest difference between the temperature of the *day* and that of the *night.*

The development of vegetation is greatest in tropical countries, and a great part of the nocturnal coling is due to the leaves, which present to the sky an immense number of thin bodies, having large surface, well adapted to radiate heat.

The annexed figure, in which arrows denote the direction of heat, and the numerals the temperatures of the earth and air under different circumstances, will render the foregoing questions on the radiation of heat, and the production of dew and frost, more intelligible.

Fig. 55.



Surface of the earth, 59°.	41°. Dew.	32°. Frost.	53°. No dew or frost.	41°. No dew or frost.
In the day-time.	In clear and serene nights.		Cloudy or windy nights.	Clear night; soil protected.

The figures in the middle of the above diagram represent the temperature of the air at a distance from the surface of the earth ; the figures in the margin, the temperature of the air adjoining the surface of the earth ; the figures below the margin, the temperature of the earth itself. The directions of the arrows represent the radiation and reflection of the heat.

Q. Does dew fall upon the ISLANDS of POLYNESIA ?

A. If at all, in very *small* quantities.

Q. What is the reason of this CURIOUS FACT ?

A. The air over the vast ocean in which these islands are situated, preserves a nearly uniform temperature *day* and *night*. The islands are comparatively of small extent, and the stratum of air cooled by the contact of the soil is warmed by mixing with the air that is constantly reaching it from the sea. This prevents a depression of temperature in the air sufficient to cause a deposition of dew.

Q. Who first originated the theory, and experimentally demonstrated the cause of the phenomena of dew ?

A. Dr. Wells, an eminent English philosopher.

CHAPTER XVII.

REFLECTION, ABSORPTION, AND TRANSMISSION OF HEAT.

Q. In what MANNER is heat emitted from a body distributed ?

A. It passes from the surface in *right lines*, equally in all directions, like radii drawn from the centre to the surface of a sphere: so that a thermometer placed at the same distance on any side would stand at the same point, if the effect of the ascending current of hot air could be averted.

Q. When rays of heat fall upon the SURFACE of a solid or liquid substance, what is the effect ?

A. They may rebound from its surface, or be *reflected;* they may pass directly through it, or be *transmitted ;* they may be received into its substance, or be *absorbed.*

SECTION I.—REFLECTION.

Q. What is meant by the REFLECTION of heat?

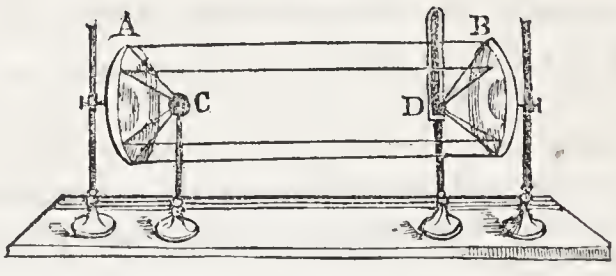
A. Heat is said to be reflected when it is caused to *rebound*, or be *thrown back*, from the surface of a reflecting body.

Q. In what MANNER is heat reflected?

A. In *right lines*, in the same manner that light is reflected.

This may be rendered evident by reference to the apparatus represented in *fig.* 56.

Fig. 56.



It consists of two concave mirrors, A and B, of planished tin or plated copper, about one foot in diameter, and placed exactly opposite each other, at the distance of about ten feet. In the focus of one mirror, at C, must be placed a heated body, as a ball of iron; and in the focus of the other mirror, at D, a thermometer. The rays of heat, then, impinging on the mirror A, are reflected through the air to the mirror B, whence they converge to its focus at D, and produce an effect on the thermometer proportioned to the degree of heat of the iron ball or other heated body.

Q. Are the best ABSORBERS the best REFLECTORS of heat?

A. No; all light colours and bright surfaces *reflect heat best*, but at the same time are the *worst absorbers* of it; the principles of absorption and reflection are so different that they cannot exist to any great extent in the same substance.

Q. What is the DIFFERENCE between REFLECTION and ABSORPTION?

A. Absorption *sucks* or *draws in heat* to itself; reflection *throws off heat* from itself; so that absorption and reflection cannot be going on at the same time in the same body.

Q. Is not METAL used as a REFLECTOR?

A. It is; polished metal being an excellent reflector of heat.

Q. Is not POLISHED metal also a conductor of heat?

A. Only when heat is brought into *actual contact* with it.

Q. What is MEANT by ACTUAL CONTACT?

A. Such as thrusting a piece of metal into the fire.

Q. By what OTHER MEANS is HEAT communicated to the metal?

A. When polished metal is employed as a reflector the heat *falls upon it in rays*, and is reflected back again with an intensity proportionate to the brightness of the metal.

Q. Why should a REFLECTOR be kept very CLEAN, and free from all SCRATCHES?

A. Because if a reflector were *spotted*, *dull*, or *scratched*, it would *absorb* heat instead of *reflecting* it; and consequently would be of no use whatever as a *reflector*.

Q. Why will not a POLISHED TIN PAN bake bread as well as an IRON one?

A. Because the *bright* metal *reflects* the heat, and therefore will not *brown* the crust which surrounds the bottom and sides of the pan; consequently, the top of the bread would be *burnt* before the bottom and sides of the loaf were *brown*.

Q. Are LIGHT COLOURS good reflectors of HEAT?

A. They are, and on this account white dresses are commonly worn in summer time.

Q. Are not WHITE DRESSES SO WARM as DARK ones?

A. No; dark colours *absorb* heat; light colours *reflect* it; therefore light colours are *cooler* to wear than dark colours.

Q. Why do not the solar rays, even in the hottest day, MELT the SNOW upon the tops of high mountains, which are nearer to the sun than the level portions of the earth?

A. Because they only heat those bodies which can *absorb their warmth*, as the rough surface of the earth. The snow is indeed struck by the rays of the sun, but being a white and shining body, it *reflects* them, and remains cold.

Q. How is it that the SUMMITS of lofty mountains, as the Alps, remain frozen even in the warmest weather?

A. Two reasons may be assigned: heat is absorbed by the air which flows up the sides of the mountain, and as the air is heated, not by the passage of the solar rays, but by contact with the earth, and as the summit of a lofty mountain presents a very limited space for such contact, the air remains intensely cold.

Q. Can we SEE the rays of reflected heat?

A. No; the rays of heat are *invisible*, and we know them only by their *effects;* yet they are governed in many respects by the same laws which belong to light, are reflected at the same angles, and may be concentrated in a focus.

Q. ENUMERATE some of the best reflectors of heat.

A. Of 100 rays falling at an angle of 60° from the perpendicular, *polished gold* will reflect 76; *silver*, 62; *brass*, 62; *brass without polish*, 52; *polished brass* varnished, 41; *looking-glass*, 20; *glass plate* blackened on the back, 12; and *metal plate* blackened, 6.

SECTION II.—ABSORPTION.

Q. What is MEANT by CONDUCTING heat?

A. The *transmission* or *conveyance* of heat from one body to another.

Q. What is MEANT by ABSORBING heat?

A. The *drawing in* or *sucking up* of heat into any substance. Thus blotting-paper *absorbs* ink.

Q. Are good ABSORBERS also good CONDUCTORS of heat?

A. No; black cloth *absorbs* heat, but does not *conduct* it; iron is a *good conductor*, but a *bad absorber*. A piece of metal, as a needle,

heated at one end conducts heat to the other end; but a piece of black cloth, though intensely hot at one part, does not conduct heat to another part.

Q. If a piece of BROWN PAPER be submitted to the action of a BURNING-GLASS, it will catch fire much sooner than a piece of WHITE PAPER would; explain the reason.

A. Because *white* paper *reflects* the rays of the sun, or throws them back; in consequence of which it appears more luminous, but is not so much heated as dark *brown* paper, which *absorbs* the rays, and readily becomes heated to ignition.

Q. Why is the TEMPERATURE of ISLANDS more EQUABLE than that of CONTINENTS?

A. Because the *water* around the island *absorbs* the extreme heat of summer, and *gives out* heat to mitigate the extreme cold of winter.

Q. ISLANDS are WARMER in winter than continents: explain the reason of this.

A. Unless the *sea be frozen* (which is rarely the case), it is warmer than the frozen land; and the warmth of the sea-air helps to mitigate the intense cold of the land air.

Q. How does the ceaseless CHANGE of air tend to DECREASE the WARMTH of a naked body?

A. The air (which cases the body) absorbs as much heat from it as it can while it remains in contact; being then blown away, it makes room for a *fresh coat of air*, which readily absorbs *more* heat.

Q. Does the AIR which encases a naked body become (by contact) as WARM as the BODY itself?

A. It would do so if it remained *motionless;* but as it remains only a *very short time*, it absorbs as much heat as it can in the time, and passes on.

Q. Why does FANNING the face in summer make it COOL?

A. Because the fan *puts the air in motion*, and makes it pass more *rapidly over the face;* and (as the temperature of the *air is always lower* than that of the human *face*) each volume of air *carries off some portion of its heat.*

Q. Why do persons FAN THEMSELVES in hot weather?

A. That *fresh particles of air* may be brought in contact with their faces by the action of the fan, and as every fresh particle of air *absorbs some heat* from the skin, this constant *change* makes them cool?

Q. Does a fan COOL the AIR?

A. No; it makes the air *hotter* by imparting to it the heat *out of our face;* but it cools our *face* by transferring its heat to the *air.*

Q. How does FANNING the face increase the HEAT of the air?

A. By driving the air more rapidly over the human body, and causing it, consequently, to *absorb more heat.*

Q. If fanning makes the AIR HOTTER, why can it make a PERSON feel COOLER?

A. Because it takes the heat *out of the face* and gives it to the *air.*

Q. Why does WIND generally feel COOL?

A. Because it drives the air more rapidly over our body, and this rapid *change* of air draws off a large quantity of heat. Every fresh

gust of air *absorbs a fresh portion*, and the more rapid the *succession of gusts*, the greater the quantity of heat absorbed.

Q. If the AIR were HOTTER than our body, would the WIND feel COOL?

A. No; the air would feel *insufferably hot*, as it would *add* to the heat of our body, instead of *diminishing* it.

Q. Is the AIR EVER as HOT as the human BODY?

A. In some climates it is; and when that is the case, the heat is almost insupportable.

Q. Does SOOT absorb HEAT?

A. Yes; and by thus conducting the heat more *quickly* from the fire to the water, a kettle covered with soot boils faster than one which is perfectly clean.

Q. Is this the reason of an OLD KETTLE *boiling* faster than a NEW one?

A. It is; the old kettle being *covered with soot*, and thus *absorbing heat more rapidly.*

Q. Why do we wear WHITE LINEN and a BLACK outer DRESS if we want to be warm?

A. Because the *black outer dress* quickly *absorbs heat* from the sun, and the *white linen* (being a *bad* absorbent) abstracts no heat from the warm body.

Q. Which are the WARMEST colours?

A. *Black* is the *warmest*, and then those nearest to black, as dark blue and green.

Q. Why are DARK COLOURS so much WARMER than LIGHT ones?

A. Because they *absorb heat* more abundantly than *light* ones. The order may be thus arranged: 1, black (warmest of all); 2, violet; 3, indigo; 4, blue; 5, green; 6, red; 7, yellow; and 8, white (coldest of all).

Q. What SORT of GLOVES are the COOLEST for summer wear?

A. *Lisle thread*, on account of their *absorbing* the perspiration of the hands, and *conducting* away the heat.

Q. Why does HOARFROST remain on LIGHT-COLOURED STONES long after it has melted from GRASS and GRAVEL WALKS?

A. Because the stones (being *white*) do *not readily absorb heat*, like the darker grass and gravel; in consequence of which, they remain too *cold* to thaw the frost congealed upon their surface.

Q. Why does the BLACK skin of a NEGRO NEVER SUN-BURN or BLISTER with the hot sun?

A. Because the *black colour absorbs* the heat, conveys it *below the surface* of the skin, and converts it into *sensible heat and perspiration.*

Q. Why does the WHITE EUROPEAN SKIN BLISTER and BURN when exposed to the hot sun?

A. Because *white will not absorb* heat, and therefore the hot sun *rests on the surface of the skin* and *burns* it.

Q. By what SIMPLE EXPERIMENT can we ascertain that BLACK prevents the SKIN from being scorched or blistered by heat?

A. By putting on one hand a *white glove*, and on the other a *black*

glove: the latter will feel the warmer, but will not be sunburnt; the former will feel the cooler, but will be sunburnt.

Q. Why does a SAUCEPAN which has been USED boil in a shorter time than a NEW ONE?

A. Because the bottom and sides are *covered with soot;* and *black soot* rapidly *absorbs the heat* of the glowing coals.

Q. Why should the LID of a SAUCEPAN be clean and BRIGHT?

A. Because it cannot *absorb heat*, as it does not come in contact with the fire; and (being bright) it will not suffer the heat to *escape* by radiation.

Q. In what state should a SAUCEPAN be, in order that it may boil MORE QUICKLY?

A. All those parts which *come in contact with the fire* should be covered with *soot*, or be black, in order to absorb heat; but all the *rest* of the saucepan should be as *bright* as possible, to prevent the *escape* of heat by radiation.

Q. Why should NOT the BOTTOM and SIDES of a kettle be CLEANED and POLISHED?

A. Because *they come in contact with the fire;* and (while they are covered with black soot) *absorb heat freely* from the burning coals.

Q. Why should the UPPER PART of a saucepan or kettle be BRIGHTLY POLISHED?

A. Because thereby the heat is *kept in*, and not suffered to *escape* by radiation.

Q. What curious CHANGE takes place in the character of solar heat when it has been RADIATED from material substances?

A. The direct rays of solar heat produce *less effect upon snow* than those which are radiated from the trunks of trees, &c.; and it can be shown that these secondary radiations are more abundantly absorbed by snow or white bodies than the direct solar rays themselves.

Q. What EXPERIMENT proves this fact?

A. If a blackened card be placed upon snow or ice in the sunshine, the frozen mass underneath it will be gradually *thawed*, while that by which it is surrounded, although exposed to the full power of solar heat, is but little disturbed. If, however, we reflect the sun's rays from a metal surface, an exactly contrary result takes place; the uncovered parts are the first to melt, and the blackened card stands high above the surrounding portion.

Q. How can this phenomenon be explained?

A. The cause is *not known.* Science here discloses to us an intimate connection between the most ethereal and grosser forms of matter. "Heat, by touching the earth, appears to become more earthlike."

Q. Why do most of the animals inhabiting the frigid zones have WHITE fur, hair, or feathers?

A. Because white *radiates* and *absorbs* but little heat.

Q. What RELATION exists between the power of bodies to absorb and communicate heat?

A. Those bodies which *absorb* heat *freely*, also *part with it most rapidly;* that is, they are sooner heated and more speedily cooled than other bodies.

Q. At what TEMPERATURE do metals burn when handled?

A. Metals cannot be handled when raised to a temperature of more than *one hundred and twenty degrees.*

Q. At what temperature does water scald?

A. At *one hundred and fifty degrees.*

Q. To what extent can the human system sustain the influence of heated air?

A. Workmen enter ovens, in the manufacture of moulds of plaster of Paris, in which the thermometer stands 100° *above the temperature of boiling water*, and sustain no injury.

Q. Why is there so GREAT a DIFFERENCE between the burning temperature of metals and air?

A. The metals absorb heat *quickly*, and part with it *freely;* the air absorbs heat *very slowly*, and does not readily part with it.

Q. What CURIOUS EXPERIMENT was made by Sir Joseph Banks in reference to the influence of heated air?

A. He entered an oven heated 52° *above the boiling point*, and remained there some time without inconvenience. During the time, eggs, placed on a metal frame, were roasted hard, and a beefsteak was overdone. But though he could thus bear the contact of the heated air, he could not bear to touch any metallic substance, as a watch-chain, money, &c.

SECTION III.—TRANSMISSION OF HEAT.

Q. What CLASS of BODIES interfere most with the transmission of heat?

A. *Transparent media* of great density, as the *diamond*, *rock-crystal*, *glass*, and *water*. Heat passes freely through *transparent bodies* of little density, as the air, or the various gases.

Q. What SUBSTANCES permit the heat to pass most freely through them?

A. *Rock-salt* admits the passage of heat more readily than any other known solid; clear glass arrests more than half the incident heat. It is remarkable that transparent alum and pure water intercept more of the rays than the deepest coloured and even opaque glasses. Solids and liquids differ in transmissibility to rays of heat in the same manner as they differ in their action on light.

Q. Does heat, accompanied by light, pass MORE READILY through dense, transparent bodies than heat without light?

A. Yes; the solar rays pass readily through *glass*, *water*, &c., the heat and light being refracted in their passage, as is shown by the action of a burning-glass; but the result is very different when the heated body is not luminous.

CHAPTER XVIII.

EFFECTS OF HEAT.

Q. What effect has HEAT upon substances generally?

A. It *expands* them, or enlarges their dimensions.

Q. Are the DIMENSIONS of every kind of matter regulated by heat?

A. They *are;* its increase, with few exceptions, separates the particles of bodies to a greater distance from each other, producing *expansion*, so that the same quantity of matter is thus made to occupy a larger space; the diminution of heat has an opposite effect.

Q. Is the FORM of bodies dependent on heat, and how is this shown?

A. The form of bodies is dependent on heat. This is seen by the fact that by the increase of heat, *solids* are converted into *liquids*, and *liquids* are dissipated into *vapour;* by its decrease, vapours are *condensed* into liquids, and these become solid.

Q. If matter ceased to be INFLUENCED by heat, what would be the effect?

A. All liquids, vapours, and doubtless even gases, would become permanently *solid*, and all *motion* on the surface of the earth would be *arrested.*

Q. Does HEAT exert an INFLUENCE over most chemical phenomena?

A. Yes; there is scarcely any chemical action which is not in some degree modified by this principle. By its agency, bodies previously *separate* are made to *combine*, and the elements of *compounds* are *disunited.* An undue proportion of it is destructive to all organic and most mineral compounds.

Q. What are the THREE most apparent EFFECTS of heat, so far as relates to the form and dimensions of bodies?

A. *Expansion*, *liquefaction*, and *vaporisation.*

SECTION I.—EXPANSION.

Q. Is the AIR EXPANDED by HEAT?

A. It is, as may be seen by partially filling a bladder with air, tying it at the neck, and *laying it before the fire.*

Q. What EFFECT will be produced?

A. The air within the bladder will *expand*, until the bladder *bursts.*

Q. How is this expansion EFFECTED?

A. The particles of air are *driven* apart from each other; consequently, they occupy *more room* than before.

Q. Does heat EXPAND all matter?

A. Yes; *every* thing (that man is acquainted with) is expanded by heat.

Q. Does this account for CHESTNUTS CRACKING when ROASTED ?

A. It does; the air contained within the chestnut *expands by heat*, and, not having room to *escape*, *bursts* the shell.

Q. Does this BURSTING of the shell occasion the NOISE which we hear ?

A. The noise is caused by the *snapping* of the shell, and by the *report* of the *escaping air*.

Q. How is this REPORT OCCASIONED ?

A. The sound of the report is the result of a *violent impulse* given to the air, which occasions *rapid vibrations* in the sound-wave.

Q. Cannot chestnuts be roasted without CRACKING ?

A. Yes; by making a *slit* in the shell.

Q. What PURPOSE does this answer ?

A. It acts as a species of *safety-valve*, and enables the *heated air* to *escape*.

Q. Are the same EFFECTS caused by HEAT on other vegetable matter

A. Yes; as may very easily be perceived in the case of a *roasted apple*.

Q. What EFFECT is produced ?

A. The *air* within the apple, expanded by the heat of the fire, bursts the skin of the fruit.

Q. How much AIR is said to be contained within an apple ?

A. The *cells* inside an apple, which resemble in appearance the honeycomb, contain sufficient air to fill a space forty-eight times greater than that occupied by the bulk of the apple.

Q. How can this be ?

A. The air is condensed in the apple, but expanded by the force of heat.

Q. Are metals EXPANDED by heat ?

A. Yes; but the degree of expansion differs. Platinum, glass, soft steel, cast iron, iron slightly hammered, steel tempered, pure gold, copper, bronze, brass, silver, tin, lead, zinc, are all more or less affected by the heat, but all in different degrees.

Q. Why does chestnut and the like kinds of wood make more SNAPPING than other woods ?

A. Because the pores of these woods are *larger*, and contain *more air* than other kinds of wood.

Q. Why do SPARKS of FIRE start with a crackling sound from sticks of WOOD laid upon a FIRE ?

A. Because the expanded *air forces its way through the pores of the wood*, and carries with it that which resisted its escape.

Q. What are the SPARKS OF FIRE which burst from the WOOD ?

A. Very small pieces of *red hot* wood, separated from the log by the *force of the air*.

Q. Why does GREEN WOOD make LESS SNAPPING than DRY?

A. Because the pores, being filled with *sap*, contain *very little air.*

Q. Why does DRY WOOD make MORE SNAPPING than green?

A. Because the sap is *dried up*, and the pores are filled with *air* instead.

Q. What EFFECT has HEAT upon STONES?

A. It causes them to *snap* and *fly about.*

Q. How is this?

A. The *close texture* of the stone *preventing the escape of air* expanded by the heat, causes it to *force a passage* by *bursting* the stone and scattering the fragments.

Q. When a boy in making a FIRE-BALLOON sets fire to the prepared cotton or sponge, why is the balloon INFLATED?

A. Because the *air* of the balloon is *expanded* by the heat of the flame, and fills the balloon to its utmost capacity.

Q. Why does the BALLOON RISE after it has been inflated by the expanded air?

A. Because the same quantity of air is *expanded* and made so much *lighter* than common air.

Q. Why does SMOKE RUSH UP A CHIMNEY?

A. Because the heat of the fire *expands the air in the chimney*, which (being thus made *lighter* than the air around) *rises up the chimney*, and carries the smoke in its current.

Q. Why will a LONG chimney SMOKE, unless the FIRE be pretty FIERCE?

A. Because the heat of the fire will not be sufficient to *rarefy all the air in the chimney.*

Q. Why will the chimney smoke, unless the fire be FIERCE enough to heat ALL the air in the CHIMNEY-FLUE?

A. Because the *cold air* (condensed in the upper part of the flue) *will sink from its own weight*, and sweep the ascending smoke *back* into the room.

Q. How are houses and other buildings heated with hot air?

A. The fire is kindled in a furnace which is erected in the cellar. This fire heats the air in contact with it in the *air-chamber*, as it is called, and as heated air *always ascends*, it is forced up into the different apartments of the building.

Q. What is an AIR-CHAMBER?

A. It is an *enclosure* around the grate or stove, with openings below to admit the cold air from the cellar to rush in to supply the place of the heated air which ascends into the rooms above. Sometimes the air-chamber is supplied with cold air by pipes, which conduct the *cold air outside* of the house into the air-chamber.

Q. How is it that heat can cause material substances to EXPAND?

A. If we *assume* that heat is a peculiar species of matter, whose particles are strongly repulsive of one another, we may readily conceive that the entrance of heat into a mass will have the effect of

removing the integrant molecules to greater distances from each other, and thus the body will be made to occupy a *greater space, or expand.*

Q. To what is the influence of heat always exposed ?

A. To *cohesion*, or the force which tends to make the particles of matter approximate.

Q. In what bodies, therefore, should heat produce the GREATEST expansion ?

A. In those which are *least influenced* by cohesion; thus the force of cohesion is greatest in *solids*, less in *liquids*, and least in *aeriform substances;* and while the expansion of solids is trifling, that of liquids is much more considerable, and that of gases is far greater.

Q. Why does heat change a SOLID (like ice) first into a LIQUID and then into a GAS ?

A. Because heat drives the component particles farther *asunder;* hence a certain quantity of heat changes solid ice into a *liquid*, and a further addition of heat changes the liquid into *steam.*

Q. Do bodies continue to EXPAND so long as heat enters them ?

A. Yes; the expansion of the same body increases with the quantity of heat that enters it, so long as the form and chemical constitution of the body is preserved.

Q. How can we prove that SOLIDS expand with heat ?

A. If we take the *exact dimensions* in length, breadth, and thickness of any substance when *cold*, and measure it again when strongly *heated*, it will be found to have *increased* in every direction.

Q. Do bodies EXPAND with the increase of heat, and CONTRACT upon its withdrawal, with any degree of FORCE ?

A. Yes; the force with which bodies contract and expand under the influence of heat is *apparently irresistible*, and is recognised as one of the *greatest forces in nature.*

Q. Do solids expand in any REGULAR MANNER by the addition of heat ?

A. The amount of the expansion of solids, from the *freezing point* of water to 122°, has been found to be equal to what takes place between 122° and 212°, the *boiling point* of water.

Q. In what RATIO do solids expand above 212° ?

A. They do *not dilate uniformly* at high temperatures, but expand in an increasing ratio; that is, the higher the temperature beyond 212°, the greater the expansion for equal additions of heat.

Q. What PECULIARITY exists in the effect of heat upon the bulk of some fluids ?

A. That at a certain temperature *increase of heat* causes them to *contract*, and its *diminution* makes them *expand.*

Q. What CLASSES of LIQUIDS exhibit this peculiarity ?

A. Those only which increase in bulk in passing from the *liquid to the solid state*, and this change remarked *only* within a few degrees of temperature above their point of congelation.

Q. What is a noted example of this EXCEPTION to the general laws of heat ?

A. *Water;* ice swims upon the surface of water, and therefore

must be lighter—a convincing proof that water in the act of freezing must *expand.*

Q. What OTHER FLUIDS besides water expand with a reduction of temperature ?

A. *Fused iron*, *antimony*, *zinc*, and *bismuth*, are examples of such expansion. *Mercury* is a remarkable instance of the *reverse*, for when it freezes, it suffers a *very great contraction.*

Q. Why is the ICE produced by the freezing of SEA WATER always fresh and FREE from SALT ?

A. Because water, in freezing, if in sufficient quantity to allow freedom of motion to its particles, *expels all impurities and colouring matters.*

Q. If a solution of INDIGO be frozen, why will the ice formed be clear and colourless ?

A. Because the water in which the indigo was dissolved expels all the blue colouring matter while freezing.

Q. Why are blocks of ice generally filled with AIR-BUBBLES ?

A. Because the water, during the act of freezing, *expels the air* contained in it, and many of the liberated bubbles become lodged and imbedded in the thickening fluid.

Q. Is the FORCE created by the expansion of water in the act of freezing VERY GREAT ?

A. Yes; as an illustration the following experiment may be quoted :—Cast-iron bomb-shells, thirteen inches in diameter, and two inches thick, were filled with water, and their apertures or fuse-holes firmly plugged with iron bolts. Thus prepared, upon exposure to the severe cold of a Canadian winter, about 19° below "zero," at the moment the water froze, the iron plugs were violently thrust out, and the ice protruded, and in some instances the shells burst asunder, thus demonstrating the enormous interior pressure to which they were subjected by water assuming its solid state.

Q. What is the principal CAUSE of the rounded and weatherworn aspect of some rocks, especially the limestone and sandstone rocks ?

A. The *expansion of freezing water ;* water is absorbed into their fissures and pores by capillary attraction, and when it freezes during winter, it expands and detaches successive fragments, so that the original sharp and abrupt outline is gradually rounded and softened down.

Q. Why do trees often CRACK and SPLIT open in winter ?

A. The sap becomes *frozen*, and the expansion attendant upon such change is said to *rend them asunder* with a loud crackling or explosion.

Q. Why, in the winter, do we let the water RUN to prevent its freezing in the service-pipe ?

A. Because the *motion of the water* prevents the crystals of ice from forming or attaching themselves to the sides of the pipe.

Q. Can a LENS be made of ICE capable of concentrating the rays of the sun, with sufficient intensity to INFLAME substances ?

A. Yes; a *burning-lens* can be formed of transparent ice, of power sufficient to produce effects nearly equal to those of the glass lens.

Q. Does ice possess great ANTISEPTIC POWER?

A. Yes; provisions packed in ice will *keep fresh* for a great length of time.

Antiseptic—opposed to putrefaction.

Q. Why will ice PREVENT meats from putrefying?

A. Because the cold prevents the *chemical action* necessary to putrefaction.

Q. What is "GROUND ICE," or "ANCHOR ICE?"

A. Ice formed at the *bottom of streams or rivers.*

Q. Why does ice sometimes form first at the BOTTOM of streams and rivers, the surface of the water being most exposed to the cold?

A. The formation of "ground" or "anchor" ice occurs only when the temperature of the whole bulk of the running waters is reduced to *near* 32°, and that of the atmosphere is considerably *below such a point.* The beds of rivers consist generally of rugged rocks and stones; these contain a certain degree of heat, and part with it, not by conduction, nor by convection, to the water, but by *direct radiation through it* to a cloudless sky; thus losing their heat, they quickly cool the water in their immediate contact, and suddenly freeze it in films upon their surfaces.

Q. Why is the ground or anchor ice only formed in CLEAR WEATHER?

A. Because a cloudless sky is *essential* for the *radiation* of *heat* to take place from the rough surfaces at the bottom of the stream through the water. The ice remains at the bottom so long as radiation and the cloudless sky continue, but radiation ceases when the clouds appear.

Q. Why is this ice seen floating upon the surface in the greatest quantities in cloudy weather?

A. When the sky *clouds over*, *radiation ceases;* the solid surfaces then communicate sensible heat to the ice, or the clouds may send forth radiant heat downwards through the water to the ice in a degree sufficient to cause thawing to take place. The ice then becomes detached from the bottom, and floats down the stream. Should the temperature of the air continue low, with a clouded sky, or become lower, the ground ice is not renewed, but the river is speedily frozen over at its surface in the usual manner.

Q. Upon what does the FORMATION OF ICICLES depend?

A. Upon the *successive congelation of drops* or slender streams of water.

Q. What is ICE?

A. Water congealed by cold, or *frozen.*

Q. At what TEMPERATURE does this change take place?

A. When the temperature is reduced to below 32° of heat.

Q. Can water be cooled BELOW 32°, under any circumstances, without freezing?

A. If pure, *recently-boiled water*, be cooled *very slowly* and kept *very tranquil*, its temperature may be lowered to 21° without the

formation of ice, but the least motion causes it to congeal suddenly, and its temperature rises to 32°.

Q. Which is the LIGHTEST, ICE or WATER

A. *Ice.*

Q. How is this ACCOUNTED FOR?

A. Water is *expanded by freezing*, and the gravity is less in proportion as the *bulk is increased.*

Q. Does this EXPANSION of frozen water account for EARTHEN VESSELS being BROKEN on a FROSTY NIGHT?

A. Yes; the water *expanded by the frost*, and unable to escape at the top, in consequence of the ice there formed, *bursts* the sides of the vessel, just as water would do expanded by heat.

Q. Do not STONES very often SPLIT in WINTER?

A. Yes; and the reason of this is, that the *moisture* within them *freezes*, and the particles being thus expanded, *split* the stone into fragments.

Q. What other instance of the EFFECT of EXPANSION by COLD can you mention?

A. The *bursting of water-pipes* in frosty weather, and the *cracking* of the hard frozen ground. In both cases expanded moisture forces itself away, and bursts the particles asunder.

Q. Does not water expand by HEAT as well as by COLD?

A. Yes; it expands as soon as it is more than 42°, *till it boils;* after which time it flies off in steam.

Q. Explain the CAUSE of water EXPANDING when frozen?

A. It results from an entirely new arrangement of the particles of water. The *crystallised moisture* arranges itself in a sort of *net-work*, lines crossing each other at right angles, and consequently occupies *more* space than when in a *fluid state.*

Q. When does this EXPANSION of WATER from COLD begin to take place?

A. Water *contracts* with cold till it reaches a temperature of 40°, then it *expands* till it *freezes.*

Q. How may the expansion of water from cold be SHOWN?

A. Fill a flask with water at the temperature of 60°, and adapt to it a cork through which passes a glass tube open at both ends, about an eighth of an inch wide and ten inches long. After having filled the flask, insert the cork and tube, and pour a little water into the latter, until the liquid rises to the middle of it. On immersing the flask in a mixture of pounded ice and salt, the water at first contracts, and therefore descends in the tube, but soon after an opposite movement ensues, indicating that the mass of water, though growing colder, is expanding.

Q. What PART of a RIVER is FROZEN FIRST?

A. Generally the *surface.*

Q. Why is this?

A. The *surface* of the river is in *contact with the air*, and what *heat* it has in it, is more readily carried away by the air.

Q. Why is the BOTTOM of a river RARELY FROZEN?

A. *Water*, as soon as it becomes *colder* than 42°, *rises to the surface*, and if *frozen*, *floats* there till it thaws.

Q. Why does it FLOAT?

A. Because it is *lighter than water;* if it were *heavier*, it would *sink*, and the whole river soon become a solid block of ice.

Q. What USEFUL PURPOSE is answered by the ice FLOATING on the TOP?

A. The *frozen surface* of a river acts as a *warm covering* to the water below, and *prevents* the *cold* from *freezing* it.

Q. Does this COVERING of ice GROW THICKER if the frost continues?

A. It does; in consequence of the *heat of the water passing into the cold atmosphere*, through the ice.

Q. Are not WHOLE RIVERS sometimes converted into ICE?

A. Seldom: the frosts, however severe, scarcely ever lasting long enough to effect that change.

Q. Is RUNNING water or STILL frozen the most RAPIDLY?

A. *Still* water; because in *running* water the *heat* of the water IS *excited by the motion*, and distributed throughout the mass; and, because the *motion* of the water *prevents* the *rapid formation of the crystals.*

Q. Do ALL PARTS of a river FREEZE ALIKE?

A. No: incidental causes interrupt this; for instance, *springs* issuing from the bed of the river, *thaw the ice on the surface;* and, by keeping up continued action, render it *thinner* than at other parts.

Q. What is meant by CRYSTALLISATION?

A. The conversion of *certain substances into regular forms*, occasioned by a loss of a portion of their caloric, or heat.

Q. Is SEA WATER FROZEN as well as FRESH?

A. But rarely; though instances of the kind have occurred; and in some places the *water is always solid.*

Q. Why does not SEA WATER FREEZE as readily as FRESH?

A. Three reasons may be assigned—the *saltness* of the water; the *ebb and flow* of the water; and the *immense expanse* of the water.

Q. Will not SALT WATER FREEZE as readily as FRESH?

A. No: *fresh water freezes* when reduced to the temperature of 32°; *salt water* does *not* freeze till it is cooled down to 28°.

Q. How does the EBB and FLOW of the water INTERFERE with its FREEZING?

A. By keeping the water in *continual motion, it prevents* the crystals forming a *solid mass.*

Q. How does the EXPANSE of water INTERFERE with its FREEZING?

A. The *mass* of water is so *extensive* and so *deep* that it requires a very considerable time before it can be reduced to 408 temperature, at which the *surface* begins to *freeze.*

Q. WHERE is the SEA FROZEN?

A. In the *Arctic regions*, where masses of ice are met with eighteen hundred feet in height, and which never thaw.

Q. Will SALT DISSOLVE ICE?

A. Yes. *Water* freezes at 32°; *salt and water* at 28°; therefore if *salt* be added to *frozen* fresh water, it dissolves.

Q. Will ANYTHING ELSE DISSOLVE ICE?

A. Any *acid* will dissolve it.

Q. Which feels the COLDEST, a FROST or a THAW?

A. A *thaw* always feels *colder* than a *frost.*

Q. How is this?

A. *Frozen* water *absorbs heat from the air* as it thaws; the absence of that heat consequently makes the air colder. On the same principle, the air is much warmer during a frost, because, in being converted into ice, the water gives forth its latent heat to the air.

Q. Can water be FROZEN by ARTIFICIAL MEANS?

A. Yes; in very many different ways.

Q. Mention ONE of them?

A. A *bottle of water*, wrapped in *cotton*, saturated with *ether*, would soon *freeze;* evaporation carrying off the *heat* of the *water*, and reducing it to the *freezing point.*

Q. Why is a GLASS or EARTHEN VESSEL apt to break when HOT WATER is poured into it?

A. Because the *inside* of the glass is expanded by the hot water, and *not the outside;* so the *glass snaps* in consequence of this unequal expansion.

Q. Why is not the OUTSIDE of the GLASS expanded by the hot water as well as the INSIDE?

A. Because glass is a *bad conductor of heat*, and *breaks* before the heat of the *inner* surface is conducted to the *outside.*

Q. Why does a GLASS SNAP because the INNER surface is HOTTER than the OUTER?

A. Because the *inner* surface is expanded, and not the *outer;* in consequence of which an *opposing* force is created, which breaks the glass.

Q. Why do persons DIP a RAZOR in HOT WATER before shaving with it?

A. The edge of the razor is expanded by the heat of the water, and by that means is rendered more fine and sharp.

Q. Why does a COOPER heat his HOOPS RED HOT when he puts them on a tub?

A. 1. As iron *expands* by heat, the hoops will be larger when they are red hot; in consequence of which they will fit on the tub more easily; and

2. As iron *contracts* by cold, the hoops will shrink as they cool down, and gird the tub with a tighter grasp.

Q. Why does a WHEELWRIGHT make the TIRE RED HOT which he fixes on a WHEEL?

A. 1. That it may fit on more *easily;* and

2. That it may gird the wheel more *tightly.*

Q. Why will the wheelwright's TIRE FIT the wheel MORE EASILY for being made RED HOT?

A. Because it will be *expanded* by the heat, and (being larger) will go on the wheel more *easily.*

Q. Why will the TIRE which has been PUT ON HOT, GIRD the wheel more FIRMLY?

A. Because it will *shrink* when it cools down, and therefore gird the wheel with a *tighter* grasp.

Q. What is the CAUSE of a stove making a CRACKING NOISE when the FIRE is VERY HOT, as well as when a large fire is PUT OUT?

A. The *crackling noise* is caused by *expansion* and *contraction.* Heat expands the stove, and occasions the particles of which it is composed to rub against each other, and thus produce the sound mentioned. When the heat is removed, the stove contracts, and this second disturbance of its particles produces a similar sound.

Q. If the BOILER or KETTLE attached to a kitchen range be filled with cold water some time AFTER the fire has been lighted, it will be very likely to crack or burst; why is this?

A. Because the heat of the fire has caused the metal of which the boiler is composed to *expand;* but the cold water very suddenly *contracts* again those parts with which it comes in contact; and as one part is made *larger* than the other, the boiler cracks.

Q. When the stopper of a DECANTER or smelling-bottle sticks, why will a cloth wrung out of HOT WATER, and wrapped round the NECK of the bottle, LOOSEN the stopper?

A. Because the hot cloth *heats* the neck of the bottle, causing it to *expand*, and consequently loosens the stopper.

Q. Why does the STOPPER of a decanter STICK fast if it be put in damp?

A. If the stopper be damp, it fits the decanter *air-tight;* and if the decanter was last used in a heated room, as soon as the hot air enclosed in the inside has been condensed by the cold, the weight of the external air will be sufficient to press the stopper down and make it stick fast.

Q. Why does the STOPPER of a SMELLING-BOTTLE very often STICK fast?

A. Because the contents of a smelling-bottle are very volatile, and leave the neck of the bottle and the stopper damp.

If the smelling-bottle was last used in a hot room, as soon as the hot air and volatile essence inside the bottle have been condensed by the cold, the weight of the external air will be sufficient to press the stopper down and make it stick.

Q. Why are the NAILS in almost all old houses LOOSE and easily DRAWN OUT?

A. Because the iron *expands* in the *summer*, and *contracts* in the *winter*, more than the stone or wood, and thus the opening is gradually enlarged after a lapse of time.

Q. Why does a piano give a HIGHER TONE in a cold than in a warm room?

A. Because in a cold room the strings are *contracted and tighter.*

Q. Why, in roofing, are the metal plates made to OVERLAP each other, instead of being nailed together?

A. In order that they may neither *tear* nor *warp* by *alternate contraction and expansion.*

Q. Why do CLOCKS go slower in summer and faster in winter?

A. Because the *pendulums elongate* in summer through the effects of heat, and consequently vibrate slower; while in *winter they contract*, become shorter, and vibrate more rapidly.

Q. How is this INEQUALITY in the rate of motion in time-pieces obviated?

A. By what is called a *compensating pendulum;* that is, one constructed of two metals, possessing different expansive powers, in such a manner that the greater expansion of one bar in one direction equals the less expansion of other bars in a different direction, and thus maintain an invariable length of the pendulum.

Q. Does WOOD EXPAND under the influence of heat differently from metal?

A. Yes; an iron bar expands and contracts equally in all directions, but wood expands and contracts more in *breadth* than in *length*.

Q. Why will a person buying oil, molasses, spirits, &c., by the measure, get a GREATER WEIGHT of the same material in the same measure in the winter than in the summer?

A. Because these liquids *contract* and occupy *less space* in the winter than in summer; consequently it requires more of the same kind to fill the same space in winter than in summer.

Q. Glass chimneys, for lamps and gas-burners, are frequently cracked and broken by irregular expansion when first heated by the flame of the light: how may this liability to break be AVOIDED?

A. By making a minute notch with a diamond in the bottom of the tube.

Q. How can heat be MEASURED?

A. Only by its *effects:* since the magnitude of any body changes with the heat to which it is exposed; and since, when subject to the same calorific influences, it always has the same magnitude, these dilations and contractions, which are the constant effects of heat, may be taken as the measure of the physical cause that produced them.

Q. What is the TEMPERATURE of a body?

A. It is the *actual state* of a body at any moment, determined by a comparison of its magnitude with the heat to which it is exposed.

Q. What is a CHANGE of temperature?

A. The change in *magnitude* which a body suffers by changes in the *heat* to which it is exposed.

Q. What are the INSTRUMENTS for measuring heat CALLED?

A. *Thermometers* and *pyrometers.*

Q. What is the DIFFERENCE between them?

A. A *thermometer* is used for measuring *moderate temperatures;* while the *pyrometer* is chiefly applied to determine the more *elevated degrees* of heat.

Q. What SUBSTANCES are best adapted for measuring the effects of heat by their expansion and contraction?

A. *Liquids*, above all other substances.

Q. Why are liquids BEST ADAPTED for this purpose ?

A. Because in solids the direct expansion by heat is so small as to be seen or measured with difficulty; in air or gases it is too extensive and too liable to be affected by atmospheric pressure; but liquids are free from both disadvantages.

Q. What LIQUID is generally used for the construction of ordinary thermometers ?

A. *Mercury* or *quicksilver.*

Q. What METAL is distinguished from all others by its FLUIDITY at ordinary temperature ?

A. *Mercury* or *quicksilver.*

Q. Does mercury, like other metals, EXPAND by HEAT ?

A. It readily *expands* or *contracts* with *every variation* of temperature.

Q. Why is mercury PREFERABLE to all other liquids for the purposes of the thermometer ?

A. Because it *boils* at a *higher temperature* than any other liquid, except certain oils; and, on the other hand, it *freezes* at a *lower temperature* than all other liquids, except some of the most volatile, such as ether and alcohol.

Thus, a mercurial thermometer will have a wider range than any other liquid thermometer. It is also attended with this convenience, that the extent of temperature included between melting ice and boiling water stands at a considerable distance from the limits of its range, or its freezing and boiling points.

Q. Of what does the mercurial thermometer CONSIST ?

A. The mercurial thermometer consists essentially of a glass tube with a bulb at one extremity, and which, having been filled with mercury at a certain temperature, introduced through the open end, has been hermetically sealed while full, so that no air can afterwards enter it.

As the tube and mercury in it gradually become cooled, the enclosed fluid contracts, and consequently sinks, leaving above it a vacant space or vacuum, through which it may again expand on the application of heat.

Q. As thermometers are constructed of different dimensions and capacities, how are they GRADUATED to indicate the same temperature under the same circumstances, as the freezing point, for example ?

A. The thermometers are first immersed in *melting snow* or *ice.* The mercury will be observed to stop in each thermometer-tube at a certain height; these heights are then marked upon the tubes. Now it has been ascertained that at whatever time and place the instruments may be afterwards immersed in melting snow or ice, the mercury contained in them will always fix itself at the point thus marked. This point is called the *freezing point* of water.

Q. How is the boiling point ASCERTAINED ?

A. It has been found that at whatever time or place the instruments are immersed in pure water, when boiling, provided the barometer stands at the height of thirty inches, the mercury will always rise in each to a certain height. This, therefore, forms another *fixed point* on the thermometric scale, and is called the *boiling point.*

Q. How are the INTERMEDIATE POINTS determined?

A. In Fahrenheit's thermometer, the intervals on the scale, between the freezing and boiling points, are divided into 180 equal parts. This division is similarly continued below the freezing point to the place 0, and each division upwards from that is marked with the successive numbers 1, 2, 3, &c. The freezing point will now be the 32nd division, and the boiling point will be the 212th division. These divisions are called *degrees*, and the boiling point will therefore be 212°, and the freezing temperature, 32°.

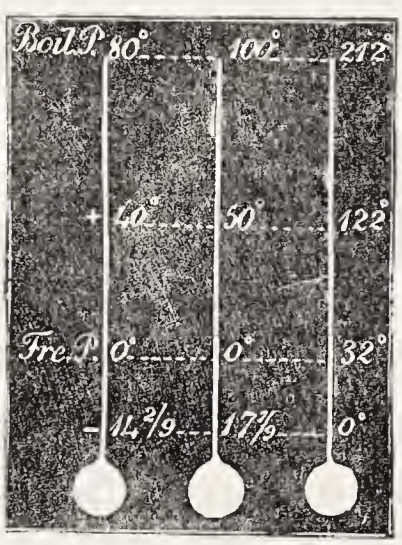
Q. When and by whom was the thermometer INVENTED?

A. The thermometer was invented about the year 1600; but, like many other inventions, the merit of its discovery is not to be ascribed to one person, but to be distributed among many.

Q. Why is the thermometer in general use in England, the United States, and Holland, called FAHRENHEIT'S thermometer?

A. Because thermometers having a like graduation were first manufactured by Fahrenheit, a Dutch philosophical instrument-maker. The employment of mercury as the most suitable fluid for the thermometer is also usually attributed to him?

Fig. 57.



Q. How many KINDS of thermometers are in general use?

A. Three; Fahrenheit's, *Reaumur's*, and the *Centigrade* thermometer, or thermometer of Celsius.

Q. What constitutes the DIFFERENCE between these instruments?

A. The differences of *graduation* between the freezing and boiling points of water. Reaumur's is divided into *eighty* degrees, the Centigrade into *one hundred*, and Fahrenheit's into *one hundred and eighty*. According to Reaumur, water freezes at 0°, and boils at 80; according to Centigrade, it freezes at 0°, and boils at 100°; and according to Fahrenheit, it freezes at 32°, and boils at 212°; the last, very singularly, commences counting not at the freezing point, but 32° below it.

The differences between these instruments can be easily seen by reference to *fig.* 57.

Q. In what COUNTRIES are the Reaumur and Centigrade thermometers generally used?

A. Reaumur is in general use in Germany, and the *Centigrade* in France; but for scientific purposes the Centigrade is almost universally adopted.

Q. How may the different thermometers be COMPARED with each other?

A. By remembering that 4° of Reaumur are as large as 5° Centigrade, or 9° Fahrenheit. In reducing Fahrenheit to Reaumur or Centigrade, if the degree be *above* the freezing point, 32° must be subtracted, which process must be reversed in order to reduce the degrees of other scales to those of Fahrenheit. To the degrees above 0°, the sign + is prefixed; to those below, the sign —.

Knowing the relation which exists between their degrees, it is easy to reduce the temperature expressed by one thermometer to that of another. Thus a degree of Fahrenheit's scale is equal to 4-9ths of one of Reaumur's, and to 5-9ths of a Centigrade degree; therefore, to convert a degree of Fahrenheit into its equivalent on Reaumur's scale, we must multiply by 4 and divide by 9; and the equivalent on the Centigrade is obtained by multiplying by 5 and dividing by 9, always remembering to previously subtract 32°, because the zero of Fahrenheit is 32° lower than either of the others. The same process reversed enables us to reduce the degrees of the other scales to those of Fahrenheit—by adding 32°, multiplying by 9, and dividing by 4 or 5, as the case may be.

Fig. 58.

Q. How is MERCURY introduced into the tube of a thermometer?

A. In order to fill the bulb of the thermometer with mercury, there is blown to the upper end of the tube a funnel, C, which is first filled with mercury; then, by inclining the tube a little to one side, and applying the heat of a spirit lamp to the bulb, the air within the latter is expanded, forced up the tube, and expelled through the funnel C.

Q, What is done next?

A. The tube is then cooled, the remaining portion of heated air contracts, and the mercury, by atmospheric pressure, is forced into the bulb D. This process is conducted over and over again, until a very small quantity of air remains in the tube. In order to expel this, the mercury is heated to ebullition, and the vapour of the mercury forces out the air. The funnel C is then removed, and the extremity hermetically sealed.

Q. Is not some other process necessary before this is done?

A. Yes; before this is done, care must be taken to expel one-half or two-thirds of the mercury in the tube; otherwise, the mercury would expand and burst the thermometer.

Q. At what TEMPERATURE does mercury FREEZE?

A. At about 39° *below the zero* of Fahrenheit's thermometer.

Q. How are degrees of cold more intense than this MEASURED?

A. By using a thermometer filled with *alcohol* coloured red, as this fluid, when pure, does not congeal at 100° Fahrenheit below zero.

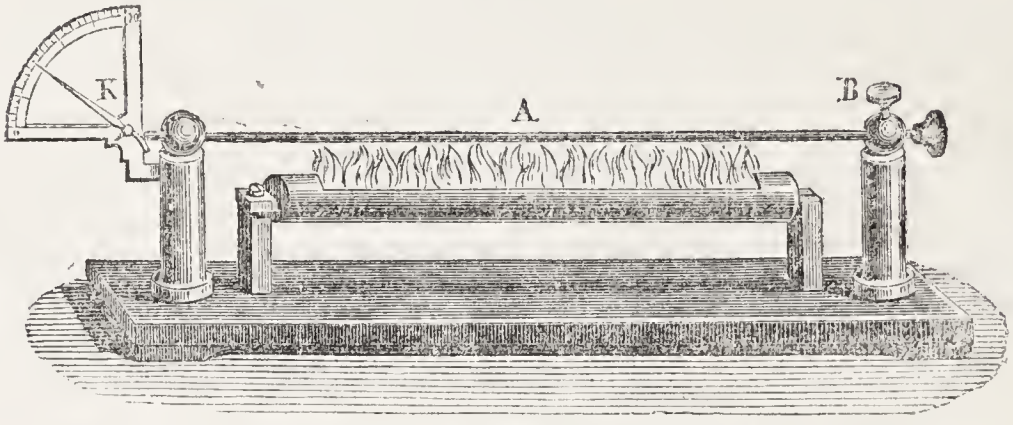
Q. At what TEMPERATURE does mercury BOIL?

A. At 656° Fahrenheit.

Q. How are temperatures GREATER than this DETERMINED?

A. By means of the *expansion of solids;* and instruments founded upon this principle are commonly called *pyrometers.*

Fig. 59.



Q. On what PRINCIPLE have pyrometers generally been CONSTRUCTED?

A. On the relative expansion of bars of iron, or some other metal. Several of these are constructed on the principle of that represented in *fig.* 59, in which a bar of metal, A, may be so placed, that when expanded by the heat of the furnace below, one extremity will press against a lever, and cause an index, K, to move along the graduated arc; and by means of such a pyrometer the effect of heat, applied in the same manner for a given length of time, to bars of different metals having the same length and diameter, may be ascertained.

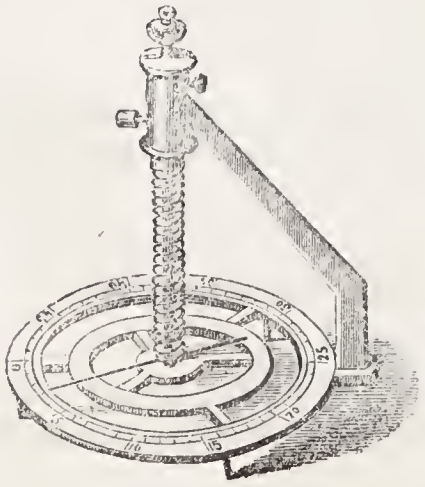
Q. By what OTHER MEANS can the cubic expansion of solids be ASCERTAINED?

A. For this purpose, a small metallic ring is sometimes used, called the ring of Gravezande, a ring through which, at the ordinary temperature, a copper sphere having nearly the same diameter readily passes. When this sphere is heated by the flame of a spirit-lamp, it can no longer pass through the ring.

Q. What OTHER KINDS of thermometers are employed?

A. A curious and useful thermometer was constructed by A. Brequet, of Paris; constructed on the principle of the unequal expansibility of metals.

Fig. 60.



This instrument is composed of three equal slips of metal—platinum, gold, and silver. After being soldered and flattened into one thin metallic ribbon, they are wound in a spiral form round a support (*see* diagram), and the upper extremity being fixed to it, there is attached to the other extremity, which is free, a needle moving over a horizontal dial. On the raising of the temperature the metals begin to expand, the silver more than gold or platinum, and the spiral unwinds itself from left to right, as shown in the figure.

Q. How do the manufacturers of porcelain and pottery sometimes ASCERTAIN the HEAT of their furnaces?

A. By employing as a pyrometer a cylinder of *fine porcelain clay*, which contracts with some degree of regularity until melting or vitrefaction takes place.

Q. Does a thermometer inform us how MUCH HEAT any body contains?

A. No; it merely points out a *difference* in the temperature of two or more substances. All we learn by the thermometer is whether the temperature of one body is greater or less than that of another; and if there is a difference, it is expressed numerically—namely, by the degrees of the thermometer.

It must be remembered that these degrees are parts of an arbitrary scale, selected for convenience, without any reference whatever to the actual quantity of heat present in bodies?

SECTION II.—LIQUEFACTION.

Q. After the expansion of solids, when acted upon by heat, what OTHER EFFECT is next observed?

A. They change their aggregate state, become liquid, or melt. Many of them become soft before melting, so that they may be kneaded; for instance, wax, glass, and iron; in this condition, glass can be bent and moulded like wax, and iron can be forged or welded.

Q. What is LIQUEFACTION?

A. Liquefaction is the conversion of a solid into a liquid by means of heat.

Q. Why is ICE MELTED by the HEAT of the SUN?

A. Because, when the heat of the sun enters the solid ice, it *forces its particles asunder*, till their attraction of cohesion is sufficiently overcome to convert the solid ice into a liquid.

Q. Why does WAX become SOFT before it turns LIQUID?

A. Because it absorbs heat sufficient to *loosen* the contact of its particles, before it has absorbed sufficient to *liquefy* the mass.

Q. Why does melted WAX become HARD when cold?

A. Because the particles collapse, and, being packed more closely together, form a solid.

The sole difference between a liquid and a solid is this: in a SOLID the particles are packed more closely together than they are in a LIQUID. The tendency of heat is to *drive* the particles *farther apart* from each other, and thus to *liquefy* solids.

Q. Explain the PHILOSOPHY of MELTED METALS?

A. When the heat of the fire enters the metal, its particles are separated, until at last the solidity is entirely lost, and the metal becomes a liquid.

Q. Why will not WOOD MELT like iron?

A. The heat of the fire, instead of melting wood, turns it to gas, smoke, and ashes.

Q. Why will HOT iron BEND more easily than cold?

A. Because it is not so *solid*. The particles are driven farther

apart by heat, and the attraction of cohesion is thereby weakened; therefore the particles can be made to move on each other more readily.

By a still further application of heat, the particles will be driven so far asunder from each other, that the solid iron will liquefy; in which state the particles will move on each other almost without resistance.

Q. In liquefaction, or the transformation of a body from a solid to a fluid state, what REMARKABLE CHANGE takes place in the character of the heat causing this transformation?

A. It *disappears*, or becomes *insensible*, during the process.

Q. The temperature of melting ice is 32°; if you pour just enough boiling water over the ice to melt it, will the TEMPERATURE of the water be INCREASED?

A. No; the heat of the water is *consumed* in melting the ice; but pour boiling water on ice-cold water, and the temperature is immediately increased.

Q. What BECOMES of the heat which disappears during liquefaction?

A. It enters into the fluid, and becomes *latent*.

Q. Does this latent heat become SENSIBLE again when the liquid is reconverted into a solid?

A. It does; and until this heat is *withdrawn* from the fluid, it cannot become solid.

SECTION III.—VAPORISATION.

Q. What is VAPORISATION?

A. Vaporisation is the conversion of a *solid* or *liquid* into *vapour*.

Q. Why does HOT IRON make a HISSING NOISE when plunged into water?

A. Because the hot iron converts into *steam* the particles of water which come in immediate contact with it; and as the steam flies upwards, it passes by other particles of water not yet vaporised; the collision produces very rapid vibrations in the air, and a *hissing* noise is the result.

Q. How is STEAM produced by the application of HEAT to WATER?

A. The globules of the liquid are separated by the *heat* of the fire, and, being made so much lighter than the air, fly off in *steam*.

Q. What DESIGNATION has been given to the condition which water and other liquids of like character assume when dropped upon very hot surfaces?

A. The "spheroidal state."

Q. Why does the liquid ASSUME this condition?

A. Because the heat which radiates from the heated surface produces, before the surface and the liquid can come into immediate contact, a quantity of vapour sufficient to support the liquid; and this vapour, being constantly removed, prevents the liquid from touching the surface.

Q. Why does the liquid evaporate more SLOWLY than it would on a surface less highly heated ?

A. Because the layer of vapour between the hot surface and the liquid prevents the *rapid* transmission of heat by conduction.

Q. Why do the drops of the liquid assume in this condition a globular or spheroidal state ?

A. The liquid rests upon a cushion of steam continuously evolved by heat from the liquid, and assumes a rounded shape as the result of the *gravity* of its particles towards its own centre.

Q. Jugglers sometimes perform the feat of plunging the hands without injury into molten lead or iron : how is this EXPLAINED ?

A. The hand is *moistened*, and when passed into the liquid metal the moisture is vaporised, and interposes between the metal and the skin a sheath of vapour. In its conversion into vapour, the moisture absorbs heat, and thus still further protects the skin.

Q. Can any one dip their FINGERS with impunity into MELTED IRON ?

A. Yes, for a few seconds; taking the precaution to first *effectually moisten the hand.*

Q. Will a RED-HOT IRON applied to the tongue BURN ?

A. Not for some time; the *moisture* of the tongue passing into the "spheroidal condition," and protecting the skin.

Q. What is the TEMPERATURE of the bubble of liquid when in the spheroidal condition ?

A. Always *below* the boiling point.

Q. Can water be poured through the meshes of a moderately fine SIEVE, the wires of which are RED HOT ?

A. No; the water assumes the spheroidal shape, and is *unable* to pass through.

Q. To what SUBSTANCES do we apply the term "VOLATILE ?"

A. To those which have a great tendency to *assume* the *gaseous* form.

Q. To what substances do we apply the term "FIXED" or "NON-VOLATILE ?"

A. To those in which the *tendency* to assume the gaseous form is *small.*

Q. Is it necessary that a solid should first become LIQUID before it can change into VAPOUR ?

A. *Most solids* do become liquefied before they vaporise; but some pass at once, on the application of heat, from the state of a solid to that of vapour, *without assuming the liquid condition.*

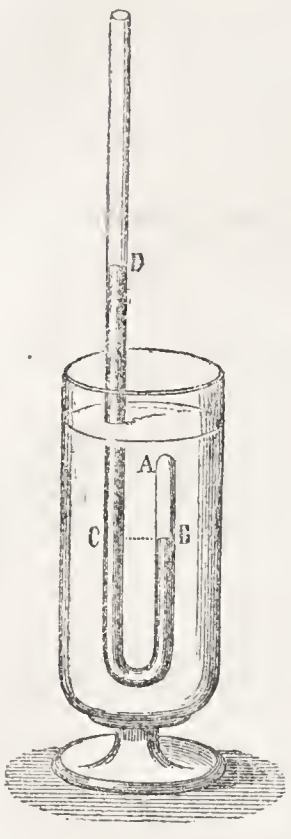
Q. Do vapours occupy much more SPACE than the substances from which they were produced ?

A. They occupy a much greater *space;* water, in passing from its point of greatest density into vapour, expands to *sixteen hundred and ninety-six times its volume.*

Q. Have VAPOURS any ELASTIC FORCE ?

A. Yes; and in consequence of this they act with a certain degree of pressure on the vessels which contain them.

Fig. 61.



Q. How is this PROVED ?

A. By experiment.

In order to ascertain the tension of vapours, a glass tube, of siphon shape, inverted, is half-filled with mercury (*see fig.* 61); then a drop of ether is passed into a shorter branch, which is closed, and the tube is then immersed in a water bath about 45° Centigrade. The mercury now sinks into the smaller branch, the space A B will be filled with a gas having entirely the appearance of air, and whose elastic force evidently balances the weight of the column of mercury C D, as well as the pressure of the atmosphere which acts on D; this gas is the vapour of ether. If we cool the water in the vessel, or if we withdraw the tube from it, which will produce the same effect, the vapour which filled the space A B will rapidly disappear, and the drop of ether will reappear. If, on the contrary, the water-bath be heated more and more, the level of the mercury will sink below the point B, and thus the tension will be increased.

Q. Is not the PRESENCE of the AIR an OBSTACLE to vaporisation ?

A. Yes; and, consequently, the experiment proceeds *slowly*. When the liquids are placed in a vacuum, the elastic force of the vapour meeting with no resistance is instantaneously developed.

Q. Why do WET clothes DRY in the air ?

A. In consequence of the evaporation of the moisture which they contain.

Q. What is this CALLED ?

A. *Spontaneous evaporation.* Thus a vessel full of water and open to the air gradually empties itself by evaporation; and thus, also, vapours rise from the seas, lakes, rivers, and earth, condense in the air, and fall again in showers of rain.

Q. What CAUSES have an INFLUENCE on the rapidity of evaporation ?

A. 1st. The temperature; 2nd. The quantity of the same vapour already in the surrounding atmosphere; 3rd. The renewal of the atmosphere; 4th. The extent of the surface evaporated.

Q. How does the temperature AFFECT vaporisation ?

A. By increasing the *elastic* force of the vapour it accelerates the evaporation.

Q. How does the CONDITION of the atmosphere AFFECT it ?

A. If the atmosphere be already completely changed and saturated with the *same* vapour as that which we desire to evaporate, it is obvious that it can take up no more.

Q. What is meant by the RENEWAL of the atmosphere ?

A. If the air is *changed*, vaporisation can, of course, procced more rapidly, on the principle last stated.

Q. How does the EXTENT of the surface evaporated AFFECT vaporisation ?

A. The greater the surface from which the vapours can *escape* into the air, the more readily and rapidly will vaporisation be complete.

Q. Under what TWO HEADS does the subject of vaporisation divide itself?

A. Into ebullition and evaporation.

Q. What is the DIFFERENCE between EBULLITION and EVAPORATION?

A. In ebullition the production of vapour is so rapid, that its escape gives rise to a *visible commotion* in the liquid; in evaporation the vapour passes off *quietly* and *insensibly*.

CHAPTER XIX.

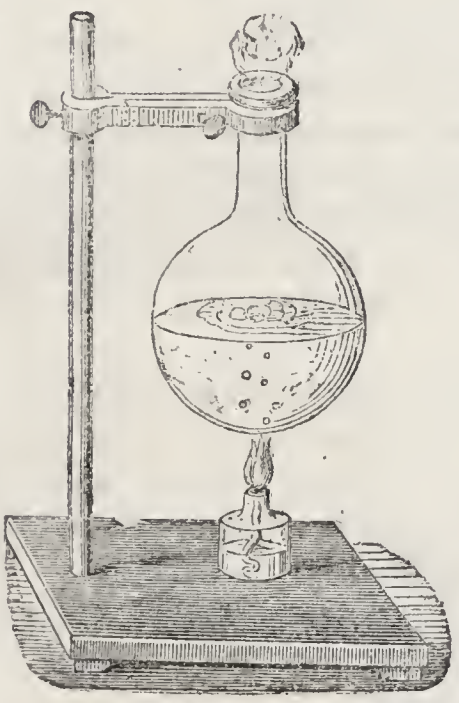
EBULLITION AND EVAPORATION.

SECTION I.—EBULLITION.

Q. What is MEANT by EBULLITION?

A. To the rapid production of vapour in bubbles of a larger or smaller size in the *same* liquid, we give the name ebullition or boiling.

Fig. 62.



Q. What are the PHENOMENA of EBULLITION?

A. A liquid substance, heated from without, passes into the form of vapour chiefly in that part where the heat is most intense. When heat is applied to the bottom of a vessel, the vapour rises in *bubbles* through the water to the surface. (*See fig.* 62.)

Q. Does EBULLITION commence at a FIXED temperature?

A. Yes; but the temperature is different in different liquids.

Q. Does the temperature INCREASE as EBULLITION proceeds?

A. No. Whatever may be the intensity of the source of heat, the temperature remains stationary from the moment ebullition begins.

Q. What do we mean by the BOILING POINT of a liquid?

A. The temperature at which vapour rises with sufficient freedom to cause the phenomenon of *ebullition* is called the boiling point.

Q. Why does BOILING WATER SWELL?

A. Because it is *expanded* by the heat; the heat of the fire driving the particles of water farther apart from each other, and making them, consequently, take up more room; in other words, the water swells.

Q. What is meant when it is said that "HEAT drives the PARTICLES of water farther APART from each other?"

A. Water is composed of little globules, like very small grains of

sand; the heat drives these particles away from each other, and (as they then require more room) the water swells.

Q. Why does BOILING WATER BUBBLE?

A. Because the *vapour* (rising through the water) is *diffused*, and forces up bubbles in its effort to escape.

All the *air* of water is expelled at the commencement of its boiling.

Q. At what TEMPERATURE do LIQUIDS BOIL?

A. Ether, 100°; alcohol, 173½°; water, 212°; water, with one-fifth salt, boils at 219°; syrup, 221°; oil of turpentine, 314°; sulphuric acid, 472°; linseed oil, 640°; mercury, 656°.

Q. Is the boiling point of the same liquid always CONSTANT?

A. Yes, under the *same conditions;* but it is liable to be affected by various circumstances.

Q. Will water boil any QUICKER in a METALLIC vessel than in a vessel of GLASS?

A. It was observed by Gay Lussac that pure water boils precisely at 212° in a metallic vessel, and at 214° in one of glass.

Q. To what CAUSE is this difference ascribed?

A. To the fact that the water *adheres* to glass more powerfully than to a metal.

Q. What effect does it have if water is boiled in a GLASS vessel, the sides of which have been previously washed with SULPHURIC ACID?

A. The presence of the acid so promotes the *contact* and *adhesion* of the glass and water, that the boiling point is raised to 221°.

Q. Why will boiling take place more uniformly, and at a somewhat lower temperature, if the sides of the vessel be uneven, or when metallic filings, wire, &c., are introduced?

A. The formation of vapour in a mass of boiling liquid takes place principally at the *edges* of any solid bodies that may be contained in it; and the introduction and presence of *uneven substances* facilitates its formation.

Q. What OTHER CAUSE has a powerful influence in regulating the boiling point of liquids?

A. *The pressure of the atmosphere.* If the pressure be less than usual, then the boiling point of water and all other liquids will be lower than usual; if the pressure increases, and the barometer rises, the temperature of ebullition will be proportionably increased.

Q. If the atmospheric PRESSURE be entirely REMOVED, or if water be made to boil in a vacuum, at what TEMPERATURE will EBULLITION commence?

A. At a point 140° *lower* than in the open air.

Q. Why is not a TIN vessel containing water DESTROYED BY FIRE, in the same way that a similar vessel would be, if placed upon the fire WITHOUT any water?

A. Because the water *absorbs* the heat communicated by the fire to the metal, and discharges it with the steam produced. The bottom of the tin vessel, so long as it contains water, can never *exceed* the temperature of the water; but if the water is absent, the metal *retains* the heat, and the vessel is soon burnt or melted.

Q. What is DISTILLATION?

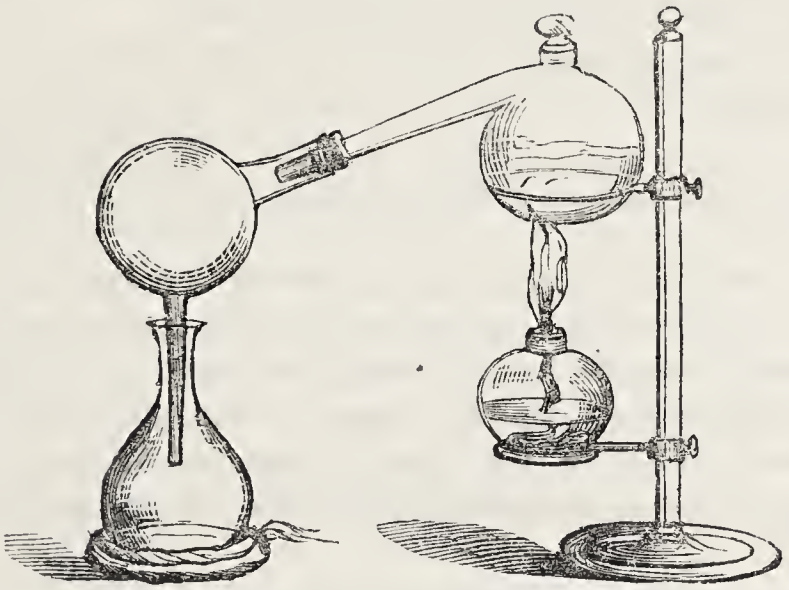
A. A process by which one body is *separated from another* by means of *heat*, in cases where one of the bodies assumes the form of

vapour at a lower temperature than the other; this first rises in the form of vapour, which is received and condensed in a separate vessel.

Q. How is the PROCESS of simple distillation EFFECTED ?

A. A peculiar-shaped vessel, called a *retort* (*fig.* 63), is half filled with a volatile liquid and heated; the steam, as it forms, passes through the neck of the retort into a *glass receiver* contained in a vessel filled with *cold water*, and is then *condensed.*

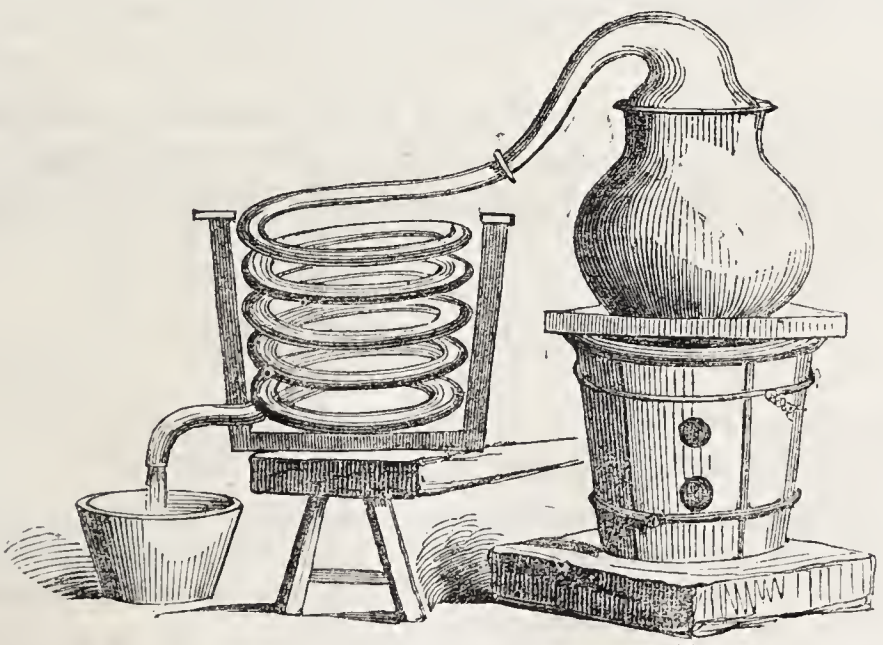
Fig. 63.



Q. When the vessel used for generating the vapour is VERY LARGE, what is it CALLED ?

A. A "*still;*" and for condensing the vapour, vats are constructed, holding serpentine pipes or "*worms,*" which present a greater condensing surface than if the pipe had passed directly through the vat.

Fig. 64.



To keep the coil of pipe cool, the vats are filled with cold water. (*See fig.* 64.)

In this figure a furnace is represented, in which is fixed a copper vessel to contain the fluid. Heat being applied, the steam rises in the head, and passes through the worm, which is placed in a vessel of water—the refrigerator. The vapour thus generated is condensed in its passage, and passes out as a liquid by the external pipe into a receiver

Q. Why is water obtained in this manner by distillation PURER than spring water?

A. Because the non-volatile, earthy, and saline portions contained in all spring waters do not *ascend with the vapour*, but *remain in the retort*. By this means very volatile bodies can be easily separated from less volatile ones; as brandy and alcohol from the less volatile water which may be mixed with them.

Q. Do some substances deposit their vapours in a SOLID form?

A. Yes; *sulphur*, *camphor*, *arsenic*, &c., when vaporised by heat, deposit their condensed vapours in a solid form.

Q. What is this PROCESS termed?

A. *Sublimation.*

Q. What BEAUTIFUL APPLICATION in the arts has been made of the fact that liquids boil at much LOWER TEMPERATURE when freed from the pressure of the atmosphere than in the open air?

A. In the *refining of sugar*, if the syrup is boiled in the open air, the temperature of the boiling point is *so high* that portions of the sugar become *decomposed* by the excess of heat, and lost or injured; the syrup is therefore boiled in *close vessels* from which the air has been previously *exhausted*, and in this way the water of the syrup may be evaporated at a temperature so low as to prevent all injury from heat.

Q. What is the IFFERENCE between drying by heat and distilling?

A. In the one case, the substance vaporised, being of no use, is allowed *to escape* or become *dissipated* in the atmosphere; while in the other, being the valuable part, it is *caught and condensed* into the liquid form.

Q. What is the VAPOUR from damp linen?

A. The vapour from damp linen, if caught, would be *distilled water.*

Q. What is the VAPOUR given out by WHEAT BREAD during the process of baking?

A. The vapour given out by bread while baking would, if collected, be a *spirit*, like that obtained in the *distillation of malt.*

SECTION II.—EVAPORATION.

Q. What is EVAPORATION?

A. The conversion of a fluid into *vapour.*

When vaporisation takes place only from the surface of a body, either because the heat has access to that part, or because the evolution of vapour takes place through the medium is a gas or air already present, the action can only be recognised by the diminution of the bulk of the body: this phenomenon is called evaporation.

Q. What EFFECTS are produced by evaporation?

A. The substance vaporised *absorbs heat* from the body whence it issues; and the body, deprived of a portion of its substance by evaporation, loses heat.

Q. Why does WATER freeze under the RECEIVER of an AIR-PUMP when ETHER is present and the AIR exhausted ?

A. Because *evaporation* is very greatly increased by the *diminution of atmospheric pressure;* and the ether, evaporating very rapidly, produces sufficient cold to freeze the water.

Q. Why is it customary, in very HOT COUNTRIES, to sit in rooms separated by CURTAINS instead of walls or doors, and to keep these curtains constantly sprinkled with WATER ?

A. Because curtains are bad conductors of heat; and the rapid *evaporation* of water reduces the temperature of the room ten or fifteen degrees.

Q. Why does WATERING the STREETS and ROADS COOL them ?

A. Because they part with their heat to promote the evaporation of the water sprinkled on them.

Q. Why does a SHOWER of RAIN COOL the AIR in summer time ?

A. Because the *wet earth* parts with its heat to promote evaporation; and when the earth is cooled, it cools the air also.

Q. Why does BREAD become HARD after it has been KEPT a few days ?

A. Because the *vapour* and *gases* escape, leaving the solid particles *dry*, so that they collapse and become more solid and hard.

Q. Why are GLUE, GUM, STARCH, and PASTE, adhesive ?

A. Because the water used with them rapidly *evaporates*, and leaves them solid; and they insinuate themselves so intimately into the pores of the substances with which they come in contact, that when the water evaporates the whole is one solid mass.

They lose their adhesiveness when dissolved in water, and therefore must always be suffered to become *dry* before they will hold with tenacity.

Q. Why will not lucifer matches ignite if they are DAMP ?

A. 1. Because the cold, produced by the *evaporation* of the water, neutralises the heat produced by the friction of the match; and

2. Because the damp prevents the free accession of *oxygen* to the match, without which it cannot burn.

Q. Why does water in a very EXPOSED place freeze more rapidly than that which is under cover or in a place less exposed ?

A. 1. Because *evaporation* goes on more rapidly when water is exposed, and carries away heat from the general mass; and

2. Any covering will radiate *heat* into the water below, and prevent the mass from cooling down to the requisite temperature to cause congelation.

Q. Why does PAINT often BLISTER from heat ?

A. Because the *heat*, penetrating through paint, extracts some little *moisture* from the wood, and turns it into vapour or steam. As this vapour requires room, it throws up blisters in the paint to make room for its expanded bulk.

Q. Why does the SUN or FIRE WARP WOOD ?

A. Because heat draws out the moisture from that part of the wood which faces it, and causes the heated surface to *shrink;* as, therefore, the heated surface of the wood shrinks, and is smaller than the *other* surface, it draws it into a curve, and the wood is warped.

Q. How does STARCH assist in giving a smooth GLAZED SURFACE to linen?

A. It fills up the interstices between the threads, and makes the fabric of more *uniform density.*

Interstices between the threads—that is, the small groove or space between each thread.

Q. How does STARCH STIFFEN linen?

A. By filling the interstices of the linen, by which means it is rendered more rigid and firm.

Q. What are the CHIEF CIRCUMSTANCES which influence the process of evaporation?

A. Extent of surface, and the state of the air as to temperature, dryness, stillness, and density.

Q. How does EXTENT of SURFACE influence evaporation?

A. Evaporation proceeds only from the *surface* of fluids, and, therefore, *cæteris paribus*, must depend on the extent of surface exposed.

Cæteris paribus—other things being equal.

Q. How does the TEMPERATURE of the air influence evaporation?

A. The effect of temperature in promoting evaporation may be illustrated by placing an equal quantity of water in two saucers, one of which is placed in a warm and dry, and the other in a cold and damp, situation. The former will be quite dry before the latter has suffered an appreciable diminution.

Q. How does the state of the air, as to DRYNESS or MOISTURE, influence evaporation?

A. When water is covered by a stratum of dry air, the evaporation is rapid, even when its temperature is low; whereas it goes on very slowly if the atmosphere contains much vapour, even though the air be very warm.

Q. Why are wet roads and footpaths, on some days, dried in a FEW HOURS, while on others they will continue wet, without any marks of drying?

A. In consequence of the *state of the air* in relation to the vapour with which it is charged. In the one case, it is *undercharged*, and therefore readily receives the evaporation from the roads and footways, which accordingly become dry; in the other case, it is at or near its *point of saturation*, and can receive no more vapour. The roads, therefore, remain wet, though no more rain falls.

Q. How does the STILLNESS of the air influence evaporation?

A. Evaporation is far *slower* in still air than in a current. The air immediately in contact with the water soon becomes moist, and thus a check is put to evaporation. But if the air be removed by wind from the surface of water as soon as it has become charged with vapour, and its place supplied with fresh dry air, then the evaporation continues on without interruption.

Q. How does the DENSITY of the air influence evaporation?

A. Pressure on the surface of liquids has a remarkable influence over evaporation. This is easily proved by placing ether in the vacuum of an air-pump, when vapour rises so abundantly as to produce ebullition.

Q. Is the process of evaporation confined to the SURFACE of the EARTH?

A. No; evaporation takes place from the surface of the *sea* as well as the surface of the *soil*, and from all *animal* and *vegetable* productions.

Q. "All the rivers run into the sea:" why is not the sea full?

A. Because the quantity of water evaporated from the surface of the sea is *equal* to the quantity poured into it by the rivers; therefore the sea is never full.

Q. Why is it frequently COOLER after rain?

A. Because water which falls from the atmosphere soon returns to it in the form of *vapour*, carrying with it, in the latent form, a large amount of heat taken from every object, thus moderating the temperature of the earth, and refreshing the animal and vegetable creations.

Q. Does evaporation take place from the surface of SNOW and ICE?

A. Yes, to a very considerable extent, even when the temperature of the air is *below* the freezing point.

Q. What very singular FACT has been noticed to exist in regard to the diffusion of vapours throughout the atmosphere?

A. That the vapours of some bodies arise in quantity and density into any space filled with air, in the same manner as if air were not present, the two fluids seeming to be *independent* of each other.

Q. Can AS MUCH vapour of water be forced into a vessel FULL OF AIR as into one from which the air has been EXHAUSTED?

A. Yes; precisely the *same* quantity.

Q. What, then, is the only way in which we can PREVENT the dissipation of a volatile body by heat?

A. By enclosing it in an atmosphere composed of the substance of the *body itself*. Thus we can save camphor, musk, volatile oils, spirits, water, &c., by placing them in closed bottles or vessels, in which, in addition to the air present, an atmosphere of their own substance is formed, involving the remaining masses with a pressure proportioned to their temperature and density.

CHAPTER XX.

STEAM.

Q. What is STEAM?

A. The *vapour* of boiling water.

Q. Is STEAM INVISIBLE?

A. Yes; but as soon as it comes in contact with the atmosphere it *condenses*, and instantly becomes visible.

Q. How can you ascertain that STEAM is INVISIBLE?

A. By observing the spout of a boiling kettle, from which steam is escaping; for the distance of about half an inch from the spout the steam is *invisible*, though it is afterwards clearly seen.

Q. How do you account for the STEAM being INVISIBLE for half an inch?

A. As it first escapes, the air is not able to *condense* it; as it becomes more *diffused*, condensation takes place.

Q. Does air ever exist WITHOUT STEAM or vapour of water?

A. Air without steam (theoretically called dry air) is not known to *exist in nature*, and is probably not producible by art.

Q. Is the VISIBLE MATTER, popularly called steam, really TRUE STEAM?

A. By no means, and should be carefully distinguished from steam proper, or the aeriform state of water. The cloud or smoke-like matter alluded to is really not an air or vapour at all, but a dust-like cloud of minute bodies of *liquid* water, wafted by a current either of true steam, or, more frequently, of mere moist air.

Q. Is it necessary to the production of steam that water should be raised to the BOILING TEMPERATURE?

A. It is not; the surface of any watery liquid, *about* 20° *warmer* than *any* superincumbent air (however warm or cold that may be), rapidly gives off true *steam*, which is invisible, but which no sooner mixes with colder air than it is recondensed into water, and assumes the form of minute globules.

Q. What causes the visible WHITE APPEARANCE of condensed steam?

A. The myriads of *minute globules* of water into which the steam is condensed are separately invisible to the naked eye, but each, nevertheless, reflects a minute ray of white light. The multitudes of these reflecting points, therefore, make the space through which they are diffused appear like a cloudy body, more or less white according to their abundance.

Q. In what respects does steam agree with common air in its MECHANICAL and OPTICAL properties?

A. Like air, steam always fills any *artificial space*, however large, that may be allowed it, and always presses equally in every direction against the whole of the enclosing surface, and with a pressure which (other things being equal) diminishes in the same ratio that the space is enlarged, and increases in the same ratio that the space is diminished. Although, like air, it has an appreciable and unalterable weight, it is always many times rarer than any liquid or solid, and when pure it is always invisible and odourless.

Q. In what manner is the production of steam in boiling water first manifested?

A. When steam begins to be produced, as in the process of making water boil, and the heat overcomes the atmospheric pressure on the surface, small bubbles are formed, adhering slightly to the sides of the vessel, as may be conveniently observed by using a Florence flask, or any other thin glass vessel.

Q. In what PARTS of the boiler will its development be most conspicuous?

A. The bubbles are formed most rapidly at those points against which the flame is most strongly directed.

Q. How much LIGHTER is steam than water?

A. About 1,700 times; because a quantity of water yields nearly 1,700 measures of steam at 212° F.

Q. How MUCH STEAM will a cubic inch of water furnish?

A. A cubic inch of water expands into about a *cubic foot of steam* at 212° F., under the ordinary atmospheric pressure.

Q. Upon what does the power of steam DEPEND?

A. On the tendency which water possesses to *expand into vapour* when heated to a certain temperature.

Q. Water, when placed in a vessel over the fire, gradually attains the boiling temperature, or 212°; but afterwards, notwithstanding the heat continues to pass into it, it does not increase in temperature; what becomes of the additional heat?

A. It passes into the *steam*, and *becomes latent.*

Q. If we immerse a thermometer in boiling water, it stands at 212°; if we place it in the steam immediately above, it indicates the same. Now, how do we KNOW that steam contains MORE HEAT than boiling water?

A. If we mix an ounce of water at 212° with five and a half ounces of water at 32°, we obtain six and a half ounces of water at a temperature of about 60°; but if we mix an ounce of steam at 212° with five and a half ounces of water at 32°, we obtain six and a half ounces of water at 212°.

Q. How much MORE HEAT, therefore, does the ounce of steam at 212° contain than the ounce of water at the same temperature?

A. The steam, from which the increased heat is all derived, contains so much more heat than the ounce of water at the same temperature, as would be necessary to raise six and a half ounces of water from the temperature of 60° to 212°, or six and a half times as much heat as would be requisite to raise one ounce of water through about 152° of temperature.

This quantity of heat will, therefore, be found by multiplying 152° by six and a half, which will give a product of 983°—the excess of heat contained in an ounce of steam at 212° over that contained in an ounce of boiling water of the same temperature.

Q. Why is STEAM, when conveyed in pipes, well adapted for warming dwellings, churches, manufactories, &c.?

A. Because as it *condenses* it gives up nearly 1,000° of heat to the adjoining objects.

Q. What is the most IMPORTANT PROPERTY of steam?

A. Its *elasticity* or *pressure.* By virtue of this property, when freed from the limits which confine it, steam will dilate into any space to which it may have access.

Q. If a quantity of pure steam be confined in a close vessel, in WHAT MANNER will its pressure be exerted?

A. It will exert on every part of the interior of the vessel a certain pressure directed outwards, and having a tendency to *burst* the vessel.

Q. In what MANNER is the elastic pressure of steam DIMINISHED by EXPANSION ?

A. When the space it occupies is *doubled*, the temperature being preserved, its elastic pressure is equal to *one half;* and, in like manner, in whatever proportion the space it fills be *increased*, its elastic pressure will be *diminished* in the same proportion.

Q. In what MANNER does the ELASTICITY of steam depend on the PRESSURE under which it is formed ?

A. Steam raised from water, boiling under any given pressure, has an elasticity always equal to the *pressure* under which the *water boils.*

Thus, when water is boiled under the ordinary atmospheric pressure (when the barometer stands at 30 inches), the steam which is generated at the temperature of 212° has an elastic pressure equal to that of the atmosphere. If water be boiled under a diminished pressure, and therefore at a lower temperature, the steam which is produced from it will have a pressure which is diminished in an equal degree.

Q. As water boils at different temperatures under different pressures, does the AMOUNT of HEAT rendered latent or absorbed at different temperatures and pressures VARY ?

A. Yes; it has been found that the heat absorbed by vaporisation is always *less* the *higher the temperature* at which ebullition takes place. Thus, if water boils at 312°, the heat absorbed in ebullition will be less by 100° than if it be boiled at 212°; and, again, if water be boiled under a diminished pressure at 112°, the heat absorbed in vaporisation will be 100° more than the heat absorbed by water boiled at 212°.

Q. How GREAT a PRESSURE does steam, formed under ordinary circumstances, have to overcome before it can rise from the surface of the water ?

A. That of *one atmosphere—fifteen pounds* on every *square inch*, or *one ton* on every *square foot*—a force equivalent to the strength of *six hundred horses.*

Q. What HAPPENS when the temperature of steam, generated under ordinary pressures, is REDUCED BELOW 212° F. ?

A. It is immediately *condensed into water.*

Q. As steam sustains and elevates a weight occasioned by the pressure of the atmosphere, of fifteen pounds per square inch, what TAKES PLACE when a column of steam is IMMEDIATELY CONDENSED ?

A. The atmospheric weight will *immediately fall* with a force equal to that with which it was raised.

Q. How can steam be used to advantage for cooking vegetables, &c. ?

A. In cookery, if steam raised from boiling water be allowed to pass through meat and vegetables, it will be *condensed* upon their surfaces, imparting to them the latent heat which it contained before its condensation, thus cooking them as effectually as if they were immersed in boiling water.

Q. Is the TEMPERATURE of the water in working steam boilers ABOVE 212° ?

A. Yes; water boils, under the ordinary pressure, at 212°. If the pressure be *increased*, the boiling *temperature* is likewise *increased.* The steam rising from the water in a close boiler

presses on the *surface of the water* equally as on the surface of the boiler, and the temperature of the water *rises*.

If a boiler, containing water thus overheated many degrees beyond the boiling point, be suddenly opened, and the steam allowed to expand, the whole water is immediately blown out of the vessel as a mist by the steam formed at the same instant throughout every part of the mass. To use a common expression, "the water flashes into steam."

Q. What do we mean when we speak of HIGH-PRESSURE steam ?

A. High-pressure steam is merely steam *condensed*, not by withdrawal of heat, but by *pressure*, just as high-pressure air is merely condensed air. To obtain a double, triple, or greater pressure of steam, we must have twice, thrice, or more steam under the same volume.

Q. Is high-pressure steam, escaping from a boiler heated to 300° or more, HOTTER than low-pressure steam escaping from a boiler at 212° ?

A. No; for the instant that high-pressure or condensed steam escapes into the air, it immediately *expands* and *becomes low-pressure steam*, and is greatly cooled down by its expansion.

Q. Does high-pressure steam, acting in a boiler at a high temperature, exert a GREATER MECHANICAL and CHEMICAL POWER than low-pressure steam ?

A. It does; high-pressure steam acting upon bones, breaks up and dissolves the whole mass, extracting all the glue and fat, when ordinary steam would dissolve nothing.

In the Western States of America, where large quantities of lard are manufactured, the whole hog is exposed to high-pressure steam, and the carcass reduced in short time to a fat fluid mass.

Q. Can high-pressure steam be raised to a very ELEVATED DEGREE of heat ?

A. It can; in some of the methods lately introduced for purifying oils, &c., the temperature of the steam, before its application, is required to be *sufficiently elevated* to enable it to *melt lead*.

Q. Can steam be applied to the CARBONISATION of WOOD ?

A. It has lately been applied to that purpose: ordinary steam is conducted through red-hot pipes, whereby it attains a very high degree of temperature. It is then allowed to pass into a vessel containing wood intended to be converted into charcoal. The heated steam, penetrating into the pores of the wood, drives off the volatile portions, the water, the tar, &c., and leaves the pure carbon alone behind.

SECTION I.—THE STEAM-ENGINE.

Q. What is the STEAM-ENGINE ?

A. The steam-engine is a *mechanical contrivance* by which coal, wood, or other fuel is rendered capable of *executing any kind of labour*.

"Coals are by it made to spin, weave, dye, print, and dress silks, cottons, woollens, and other cloths; to make paper, and print books upon it when made; to convert corn into flour; to express oil from the olive, and wine from the grape; to draw up metals from the bowels of the earth; to pound and smelt it; to melt and mould it; to roll it and fashion it into every desirable form; to transport these manifold products of its own labour to the doors of those for whose convenience they are produced; to carry persons

and goods over the waters of rivers, lakes, seas, and oceans, in opposition alike to the natural difficulties of wind and water; to carry the windbound ship out of port, to place her on the open deep, ready to commence her voyage; to transport over the surface of the sea and the land persons and information from town to town, and from country to country, with a speed as much exceeding that of the ordinary wind, as the ordinary wind exceeds that of a pedestrian."—LARDNER.

Q. What SUBSTANCE furnishes the means of calling the powers of coal into activity?

A. *Water.*

Q. How MUCH WATER will two ounces of coal evaporate?

A. *About a pint.*

Q. How MUCH STEAM will this produce?

A. *Two hundred and sixteen gallons.*

Q. How much MECHANICAL FORCE can this steam exert?

A. It can raise a weight of thirty-seven tons to the height of one foot.

Q. What AMOUNT of FORCE can a man exert when applying his strength to the best advantage through the help of machinery?

A. It has been found by experiment, that a man working on a tread-mill continuously for eight hours, will elevate one and a half millions of pounds to the height of one foot.

Q. With HOW MUCH COAL will a well-constructed steam-engine perform the same labour?

A. With the expenditure of a pound and a half.

Q. How MUCH COAL then would be equivalent to the average power of an able-bodied man during his active life, supposing him to work for twenty years at the rate of eight hours per day?

A. The consumption of about four tons of coal would evolve in a steam-engine fully as much power.

Q. The great pyramid of Egypt is five hundred feet high, and weighs twelve thousand seven hundred and sixty millions of pounds. Herodotus states that in constructing it one hundred thousand men were constantly employed for twenty years. With how MUCH COAL could all the materials of this pyramid be RAISED to their present position from the ground?

A. With the expenditure of four hundred and eighty tons of coal.

Q. What is generally considered the GREATEST WORK recorded to have been performed by steam-engines?

A. The Cornish engines of England have raised *sixty thousand tons* of water a foot high with the expenditure of a *bushel of coal.*

Q. What is a CORNISH steam-engine?

A. An engine modelled after the pattern of those employed in the *tin* and *copper mines of Cornwall*, for raising water from the mines —these mines being sunk to an immense depth in the earth.

Q. Why have they obtained so great a CELEBRITY as to make them STANDARDS of reference?

A. As Cornwall produces no coal, that invaluable fuel is enhanced in price by the cost of freight from other counties; the miners were hence led to *extract* from the coal all the *heating power* they possibly could; and hence has arisen the celebrity of the steam-engines made and used in Cornwall—a celebrity due to the fact that they get more power out of a bushel of coal than any other steam-engines.

Q. When a miner or engineer wishes to calculate the relative efficiency of two engines, what STANDARD does he adopt?

A. He determines how much water can be raised to a height of *one foot* by the steam-power generated through the heat of one bushel of coal; and this he calls the "duty" of the engine.

Q. In what MANNER is steam rendered useful for mechanical purposes?

A. By its pressure.

Q. Why CANNOT steam, like wind and water, be made to act advantageously by its impulse in the open air?

A. Because the momentum of so light a fluid, unless generated in vast quantities, would be inconsiderable. The first attempts, however, to employ steam as a moving power, consisted in directing a current of steam from the mouth of a tube against the floats or vanes of a revolving wheel.

Q. In order to render the pressure of steam available in machinery, what CONDITIONS are necessary?

A. The steam must be confined within a *cavity* which is air-tight, and so constructed that its dimensions or capacity may be altered without altering its tightness.

Q. When the steam enters such a vessel, what TAKES PLACE?

A. The steam by its pressure *enlarges* the actual cavity, by causing some movable part to recede before it, and from this movable part motion is communicated to the machinery.

Q. How is such an arrangement of machinery EFFECTED?

A. By having a *hollow cylinder* with a movable piston accurately fitted to its base (as shown in fig. 65). The piston thus employed has a reciprocating motion, which is converted when necessary into a rotary one by appropriate mechanism.

Q. In a simple working engine, how may CONTINUOUS MOTION be kept up by means of the piston and cylinder?

A. The pressure of the steam, admitted into the cylinder below the piston, causes the piston to rise, and the piston-rod also rising, communicates motion to a lever connected with it. When the piston is thus raised, if the steam be suddenly condensed or withdrawn from under it, a *vacuum* will be formed, and the pressure of the atmosphere on the piston above will drive it down. It may then be raised anew by the admission of more steam, to be condensed in its turn, and in this manner the alternate motion may be continued indefinitely.

Q. What is a CONDENSING steam-engine?

It is one in which the *steam* which has been employed in raising or depressing the piston is *condensed*, after it has accomplished its object, leaving a vacuum above or below the piston.

Q. In what MANNER is the steam below the piston CONDENSED?

A. By opening at the proper time a *communication* between the cylinder and a strong vessel situated at a distance from it, called the condenser. Into this vessel a jet of cold water is thrown, which

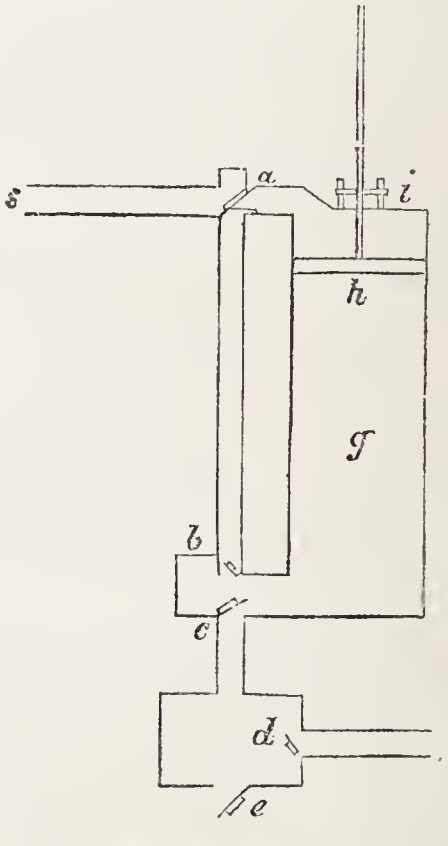
instantly condenses the steam escaping from the bottom of the cylinder into water.

Q. In this engine, does the piston descend in the cylinder by the PRESSURE of the ATMOSPHERE, in consequence of the vacuum formed beneath it by condensing the steam?

A. The piston would descend by the atmospheric pressure *alone*, and in the original atmospheric engines it did so; but in the improved engines, or the so-called double-action engines, steam is admitted into the cylinder above the raised piston at the same moment that it is removed below it; and thus the expansive force of steam is exerted in the returning as well as in the ascending stroke, and a much greater *impetus* is given to the machinery than by the old method.

In this arrangement the top of the cylinder is closed and rendered air-tight, the rod of the piston only passing through it.

Fig. 65.



The action of a condensing steam-engine may be further elucidated by reference to *fig.* 65, in which *s* represents the steam-pipe proceeding from the boiler, and by which steam is admitted to the cylinder. The piston *h* works air-tight in the cylinder *g*, the rod of which passes air-tight through the stuffing-box *i*. The upper valve box *a* contains a single valve, which, when open, admits the steam into the cylinder, and also into the pipe which connects this with the lower valve box. The lower box contains two valves, *b* and c; the valve *b*, when open, admits the steam to pass from the cylinder *above* the piston, by the connecting tube to the cylinder *below* the piston; the valve *c*, when open, admits the steam to pass from below the cylinder down into the condenser *d*. This steam entering the condenser, meets the jet of water through the valve *d*, where it is condensed. The valve *e*, opening outwards, permits any steam which is not condensed, together with such atmospheric air as is accumulated, to pass away.

The valve *a* is called the *upper steam valve; b*, the *lower steam valve; c*, the *exhausting valve;* and *d*, the *condensing valve.*

The manner in which the alternate ascent and descent of the piston is produced is as follows:—

In the first place, all the air which fills the cylinder and tubes must be expelled. To do this, the valves *a*, *b*, and *c* must be opened. The steam will pass through the pipe *s* into the upper part of the cylinder, and along the tube down through the valves *b* and *c* into the condenser *d*. After the steam ceases to be condensed by the cold of the apparatus, it will rush out, mixed with air, through the valve *e*, which opens outwards.

The apparatus is thus filled with steam, and all the valves are now to be closed; but in a few minutes a vacuum will be formed in the condenser by the cold surface of that vessel.

The apparatus being in this state, let the upper steam valve *a*, the exhausting valve *c*, and the condensing valve *d*, be opened. Steam will thus be admitted through *a* to press upon the top of the piston, the steam being prevented from circulating below the piston, by the valve *b* being closed. But the steam below the piston will rush through the exhausting valve *c* into the condenser, where a jet of cold water through the condensing valve *d* will instantly condense it, and thus leave a vacuum below the piston in the cylinder. Into this vacuum the piston is instantly pressed by the action of the steam in the upper part of the cylinder.

When the piston has thus been forced to the bottom of the cylinder, let the valves *a*,

c, and *d* be closed, and let the lower steam valve *b* be opened. The effect of this will be, that the further ingress of steam will be stopped, and the further condensation of steam will cease; and thus the steam which is shut within the apparatus will press equally on all sides, so that the pressure on the upper and under sides of the piston will be equal. Thus there is no force to restrain the piston at the bottom of the cylinder, except its weight, which is more than balanced by the weight of the pump-rod at the other end of the beam, and by the preponderance of which the piston rises as in the atmospheric engine.

When the piston has arrived to the top of the cylinder, the valves *a*, *c*, and *d* are again opened, when steam again presses on the top of the piston, while a vacuum is formed below it into which the piston is driven, as already shown, and so on continually.

Q. What OTHER NAME besides "condensing engines" is given to engines working upon this principle?

A. They are called *low-pressure engines*, because the steam employed in working them has a comparatively *low temperature*, and a moderately elastic force.

Q. What is a NON-CONDENSING or HIGH-PRESSURE steam-engine?

A. In this engine the apparatus for condensing is dispensed with, and the steam is worked at a *high temperature*, and afterwards discharged into the open air. In this engine a part of the steam is expended in overcoming the pressure of the atmosphere, and the surplus only can be applied to drive machinery.

Q. With how GREAT A PRESSURE of the steam do the high-pressure engines generally work?

A. With a pressure of thirty to forty pounds on a square inch above the atmospheric pressure.

Q. Describe the MANNER in which the high-pressure engine is made to operate.

A. The steam, in escaping from the boiler to the open air, is obliged to pass through the cylinder, the cavity of which is closed, except where it communicates *through the valves*. By the opening and shutting of these valves the steam is made to enter the cylinder alternately at each end, and escape by the opposite end. But in doing this its passage is always intercepted by the piston, so that before it can escape it must move the piston from one end to the other of the cylinder. The repetition of this movement gives motion to a *beam*, or other alternating point, from which it is communicated by a connecting rod or crank to a fly-wheel and other machinery.

Q. In what SITUATIONS are the high-pressure engines generally used?

A. Where *simplicity and lightness* are required, as in locomotive engines; also in situations where a sufficient supply of water for condensation cannot easily be obtained.

Q. How do they COMPARE in SAFETY with the low-pressure or condensing engines?

A. They are *less safe*, yet as they cost less at the outset for construction, they are often preferred.

Q. In a condensing engine, what USE is made of the WATER used for condensing the escape steam?

A. The condensing steam renders the water very hot, and it is generally *pumped back* into the boilers, thus effecting a great *economy of fuel*.

Q. How much GREATER FORCE of steam is required in a high-pressure than in a low-pressure engine?

A. In a low-pressure engine a *vacuum* (empty space) being formed on one side of the piston, the *force* of the steam required to move it is *diminished* by the amount of atmospheric pressure on the piston. But in the high-pressure engine, the piston works in *both directions* against the weight of the atmosphere, and hence requires an *additional* power of steam equal to the weight of the atmosphere on the piston.

Q. What PARTS are dispensed with in the high pressure engine?

A. *All the apparatus for condensing*—nothing more being necessary than the boiler, cylinder, piston, and valves.

Q. Of what TWO PARTS does every steam-engine consist?

A. First, that which is employed to *generate* the steam, called the *boiler;* second, that in which the *steam is applied.*

Q. What are the ESSENTIAL QUALITIES of a steam-boiler?

A. It is requisite that a boiler should be of *sufficient strength to resist the greatest pressure* which is ever liable to occur from the expansion of the steam. It must also offer a sufficient extent of surface to the fire to insure the requisite amount of vaporisation.

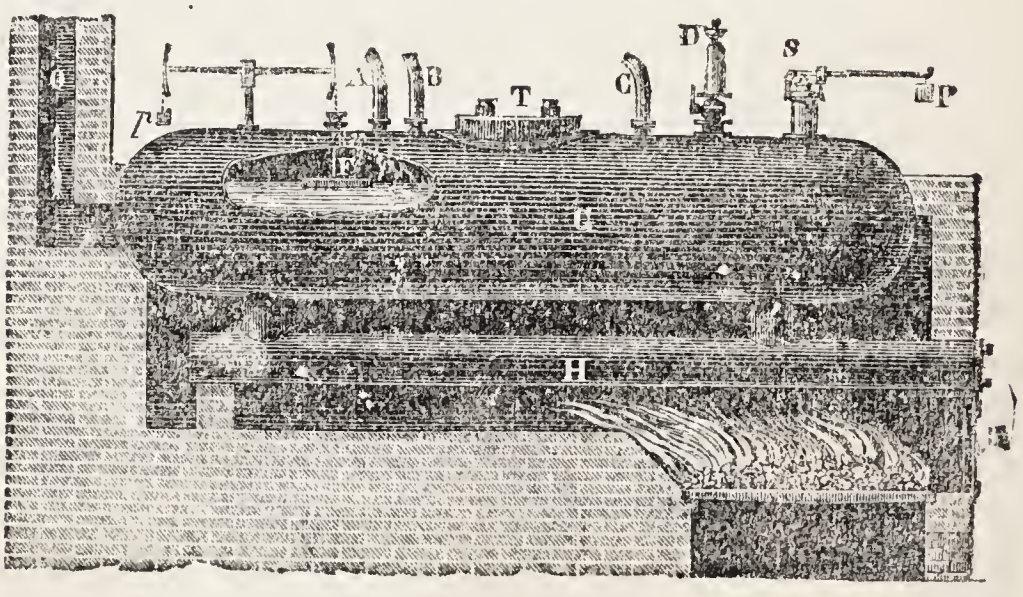
In common low-pressure boilers, it requires about eight square feet of surface of the boiler to be exposed to the action of the fire and flame to boil off a cubic foot of water in an hour; and a cubic foot of water thus converted into steam is equal to one-horse power.

Q. What is the BEST FORM for a boiler?

A. The strongest form for a boiler, and one of the earliest which was used, is that of a *sphere* or *globe;* but this form is the one which offers least surface to the fire. The figure of a *cylinder* is on many accounts the best, and it is now extensively used, especially for engines of high-pressure.

This form, usually given to the boilers of fixed engines, is seen in the accompanying diagram.

Fig. 66.



A, the tube which conveys the steam to the valve-chest; B, the tube which conveys the steam to the BAROMETER-GAUGE, or manometre, which indicates the pressure of steam in the GENERATOR; C, the tube which is used to carry water into the boiler, commonly called the FEED-PIPE; D, the STEAM-WHISTLE, which is employed to give alarm by its

noise when there is not water enough in the boiler. So long as the level of the water is not too low in the generator, the steam does not enter the whistle, but if the level sinks below a certain depth, a small float, not seen in the *fig.*, closes the bottom of the whistle, descends, and the steam is admitted. The rushing forth of the steam causes the sharp sound by striking against the edges of a metallic disc. F, the FLOAT employed to indicate the level of the water in the generator; G, the cylindrical GENERATOR, made of wrought iron, and kept completely closed; H, the BOILER-TUBES, placed side by side; O, the PASSAGE to the chimney; P, the WEIGHT which loads the safety-valve; *p*, the counter-weight of the float; R, the DOOR of the fire-grate; S, the SAFETY-VALVE; and T, the MAN-HOLE, or opening for the admission of the workmen to cleanse or repair the generator.

Q. What ADVANTAGES has a cylinder boiler?

A. It has the advantage of being *easily constructed from sheets of metal*, and the form is of equal strength except at the ends. In such a boiler the *ends* should be made *thicker* than the other parts. The furnace is so constructed that the flame and hot smoke may pass under the whole length of the boiler, and afterwards around both its sides, before escaping to the chimney.

Q. How is the so-called "FLUE-BOILER" CONSTRUCTED?

A. In this a *cylindrical furnace* is placed within a *cylindrical boiler*, so that the fuel is surrounded by water on all sides, and communicates to it nearly all its heat, except that portion which passes up the chimney.

Q. What is a SAFETY-VALVE?

A. The safety-valve is generally a *conical* or *sugar-loaf lid* fitted into the boiler, and opening outwards; it is kept down by a weight equal to the pressure which the boiler is capable of sustaining without danger from the steam generated within. If the amount of steam at any time exceeds this pressure, it overcomes the resistance of the weight, lifts the valve, and allows the steam to escape.

Q. Notwithstanding the use of the safety-valve, steam-boilers frequently BURST with terrific explosions; how is the fact to be ACCOUNTED FOR?

A. The explosion of steam-boilers, when the safety-valve is in good condition and working order, is *sometimes inexplicable;* but explosions often result from the engineer allowing the water to become too low in the boilers.

Q. How does the fact of allowing the water to become too low in the boilers tend to PRODUCE EXPLOSIONS?

A. Some parts of the boiler, being devoid of water, become highly overheated; when then water is thrown into the boiler in this condition, it comes *suddenly into contact with the intensely heated metal*, and an immense amount of steam having great elastic force is at once generated. In this case the boiler may burst before the inertia of the safety-valve is overcome, and the stronger the boiler the greater the explosion.

Q. An engine is sometimes called an expansive engine, in contradistinction to a simple high-pressure, or a condensing or low-pressure engine: what are we to UNDERSTAND by the TERM?

A. In some engines the steam from the boiler is not allowed to *press against the piston* during the whole length of the stroke, but is cut off before the piston has fully completed its ascent or descent in

the cylinder. The steam already in the cylinder immediately expands, and completes the movement already begun, thus saving a considerable quantity of steam at each movement.

To carry out this plan to the best advantage, the expansive force of the steam must be greatly increased by working it under a high pressure; that is, by having a greater amount of steam in the same space than in an ordinary low-pressure engine?

Q. What ADVANTAGE is it to use a large heavy wheel, called the FLY-WHEEL?

A. This heavy wheel, when set in motion, revolves with a considerable momentum, and will *continue to move* after the force which has been imparted to it has *ceased to act.* This momentum causes the machinery to move uninterruptedly, even if the action of the steam be less at one point than at another.

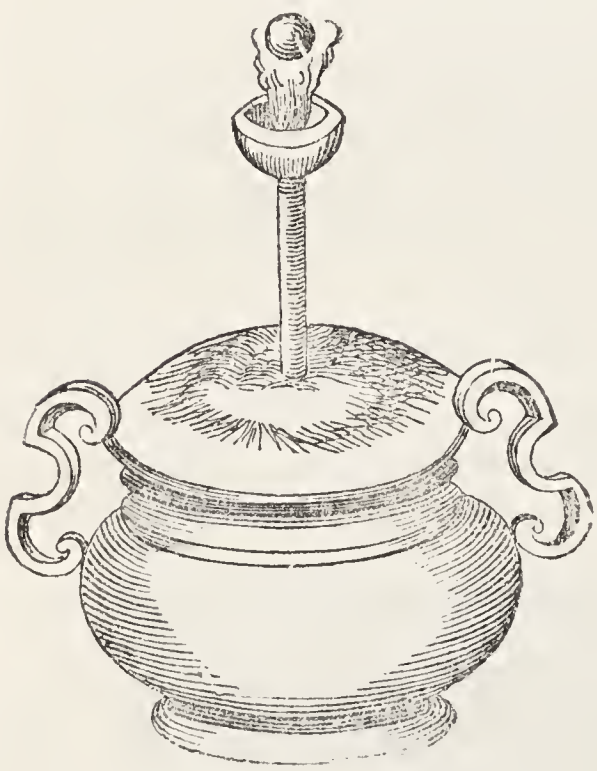
Q. Do the ANCIENTS appear to have been acquainted with the power of steam?

A. They were unquestionably, *to some extent*, although but little is known on the subject. Whatever knowledge they did possess was confined to the priesthood.

Q. What is KNOWN of these DISCOVERIES?

A. Hero, of Alexandria, who flourished about 120 B.C., has recorded the principal facts then known regarding the vapour of water.

Fig. 67.



Q. Does he DESCRIBE any MACHINES moved by STEAM?

A. Yes; one of these consists of a pot with a lid, in to which is fastened an upright tube, terminating in a perforated cup, in which is placed a movable ball. (*See fig.* 67.)

Q. What EFFECT was produced by this apparatus?

A. Steam being *generated* in the pot, and suffered to issue through the tube, communicated motion to the ball.

Q. Is not the INVENTION of a STEAM-GUN attributed to the painter Leonardo da Vinci?

A. Yes; a description and sketch of a steam-gun was discovered amongst his paintings, preserved in the library of the Institute of France.

Q. In modern times, WHO appears to have first EXPERIMENTED to any practical purpose in regard to using steam for economical purposes?

A. The power of confined steam acting by its pressure, was discovered by the Marquis of Worcester, and an account of its effect published by him in 1663. He produced a steam power sufficient to burst a cannon, and constructed a machine capable of raising water

to the height of forty feet. He has not, however, left any drawings or particular description of his machine.

Q. Who NEXT took up the subject?

A. Thomas Savery, an Englishman, who invented a method for raising water by steam in 1698.

Q. What was the NATURE of Savery's engine?

A. It consisted of a boiler, a separate steam-vessel, and pipes furnished with valves. The steam from the boiler was first admitted so as to fill the steam-vessel. It was then condensed, and a vacuum being formed, the steam-vessel was filled with water which rose from the well or mine by the *atmospheric pressure*. The steam was then readmitted, and the water in the vessel was driven upwards by the pressure of the steam to the top of the pipes, and discharged. The opening and closing of the valves regulated the passage of the water and the steam.

Q. Who NEXT introduced material IMPROVEMENTS in steam apparatus?

A. Thomas Newcomen, a blacksmith, in the year 1705. He constructed a working steam-engine, which has since been called the *atmospheric* engine. It contained a cylinder and piston, and an alternating beam, which was applied to raise water by working a pump. The steam was condensed in the cylinder itself, and the valves were moved by hand, until an attendant contrived to make the machine move its own valves by attaching strings to the working beam.

Q. How LONG did the engine of Newcomen continue to be used without material improvements?

A. For *more* than half a century, or until 1769, when the great improvements of James Watt, of England, made the steam-engine substantially what it now is.

Q. What were the GREAT IMPROVEMENTS introduced by Watt?

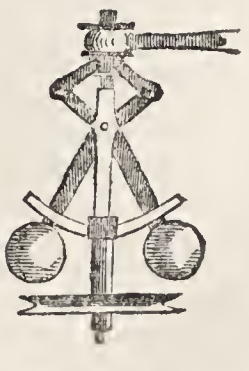
A. 1. He introduced the *separate condenser;*

2. He applied the double action of steam by *closing* the top of the cylinder, and admitting the steam alternately at each end; and

3. He converted to use the *expansive* power of steam by *cutting off* the current before the end of the stroke. He also invented the *governor* of the steam-engine, to regulate the supply of steam.

Q. What is the GOVERNOR of the steam-engine?

Fig. 68.



A. It consists (as in fig. 68) of two heavy balls, connected by jointed rods with a revolving axis; with every *increase* in the *velocity* of the engine they diverge or separate from each other, and draw downwards the jointed rods; while a slower motion of the axis causes the balls to approach each other, and the system of rods to be contracted laterally and be extended upwards.

The grand effect produced by this means depends on making the ascending and de

scending extremity of the jointed rods raise or lower the end of a bar which acts as a lever, and moves a valve which regulates the supply of steam from the principal steam-pipe.

Fig. 69.

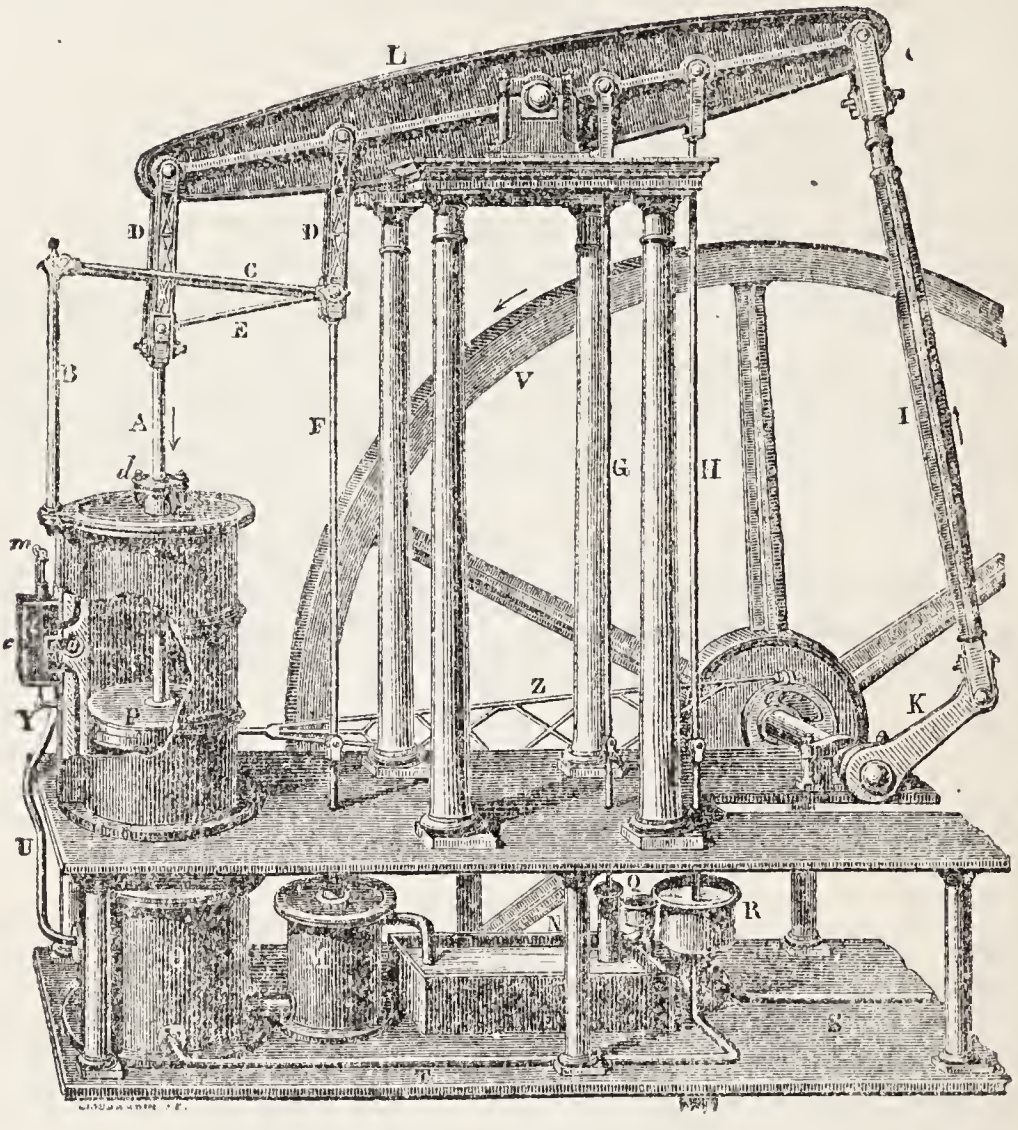


Fig. 69 illustrates the principal parts of a steam-engine, and its mode of action.

Upon the left of the figure is the cylinder, which receives the steam from the boiler. A part of the side of the cylinder is cut away, in order to show the piston, which moves alternately up and down, according as the steam is admitted above or below it. By the rod A the piston transmits its alternating movements to the walking-beam L, which is an enormous lever accurately balanced on its centre, and supported by four columns. The walking-beam L communicates its motion by means of a connecting rod I to the crank K, by which a rotary movement is communicated to the wheel V; from this the power may be applied by other wheels, or by bands and pulleys, to effect different operations.

At the left of the cylinder is an arrangement of valves and pipes, by which the steam is allowed to act alternately above and below the piston. After the steam has completed its action by forcing the piston to the extremity of the cylinder, it is necessary that it should be withdrawn, and a vacuum formed in its place. In order to accomplish this, the steam, after having acted, is caused to pass into the cylinder O, which contains cold water, and is termed the condenser. Here it is condensed, and a vacuum formed in the cylinder above or below the piston, as the case may be.

As the cold water of the condenser becomes quickly heated by the condensed steam withdrawn from the cylinder, it becomes necessary to constantly withdraw the hot water and replace it by cold water, in order that the condensation of the steam may take place as rapidly as possible. This is effected by means of two pumps; the one, F M, which is called the "air-pump," which withdraws the hot water from the condenser, and with it any air that may be present either in the cylinder or the condenser; the other, H R, called the "cold water-pump," draws from a well or river the cold water, to supply the place of the heated water withdrawn from the condenser by the air-pump. There is also

a third pump, G Q, which is called the "supply" or "feed-pump," because it pumps into the boiler the hot water which the air-pump withdraws from the condenser, thus economising the consumption of fuel.

The various parts of the engine (as shown in fig. 69) are illustrated in detail by the following descriptive explanation :—

A—Piston-rod connected with the walking-beam, and transmitting to it the alernating movement of the piston.

B, C, D, E—Arrangements of levers and joints, intended to guide and preserve the piston-rod A in a perfectly rectilinear track during its up-and-down movements.

F—Arm or rod of the air-pump, which removes the hot water and air from the condenser.

G—Rod of the "supply" or "feed-pump," which supplies to the boiler the hot water withdrawn from the condenser.

H—Rod of the cold-water pump, which supplies the cold water necessary for condensation.

I—Connecting-rod, which transmits the motion of the walking-beam L to the crank K.

M—Cylinder of the air-pump in communication with the condenser O.

O—Condenser filled with cold water, in which the steam after acting upon the piston is condensed.

P—Piston, movable in the cylinder; it receives directly the pressure of the steam upon the upper and lower surface alternately, and transmits its movements by means of the rod A to the rest of the machinery.

S—Pipe conducting the hot water withdrawn from the condenser to the boiler.

T—Pipe discharging the cold water from the cold-water pump into the condenser O.

U—Pipe conducting the steam from the cylinder, after it has acted upon the piston, into the condenser.

V—Fly-wheel.

Z—Connecting-rod, which transmits the movements of the eccentric *e* through the lever Y to the valves *b*. The eccentric is a wheel fixed upon the crank-shaft, as seen at *e*. It is called an eccentric from the circumstance of the wheel not being concentric, or having a common centre with the crank-shaft upon which it is fixed. It becomes, therefore, a substitute for a short crank, and transmits a reciprocating movement to the rod Z, which is connected with the valves at *b* by the lever Y. These valves being alternately opened and closed by the movement of the rod Z, admit the steam alternately above or below the piston.

Q. What is the difference between HIGH PRESSURE and LOW PRESSURE engines?

A. The difference exists in the *elastic force of the steam;* when the force of the steam is slight, the engine is said to be a low-pressure; when the force of the steam is great, it is said to be high-pressure.

Q. What is ATMOSPHERIC PRESSURE?

A. The *pressure of the air*, which amounts on an average to fifteen pounds on every square inch.

Q. How does the PRESSURE of the ATMOSPHERE affect the STEAM-ENGINE?

A. As the piston of the *non-condensing engine* is subject to this atmospheric pressure, namely, fifteen pounds on every square inch, it naturally follows that the pressure of the steam by which that piston is moved exceeds the pressure of the atmosphere.

Q. To what EXTENT does STEAM PRESSURE exceed that of ATMOSPHERIC PRESSURE?

A. If the pressure of the atmosphere be *fifteen pounds* on every square inch, and the pressure of the steam be *eighteen pounds* on every square inch, that is, *three pounds more* than the *ordinary weight of the air*, the engine is said to be low-pressure. If the pressure of the steam be *fifty-nine* or *sixty pounds* on every square inch, which is *four times* as much as the weight of the atmosphere, the engine is said to be high-pressure.

Q. What is a CONDENSING engine?

A. A condensing-engine is one which, being supplied with a condenser, *liquefies the steam*, after it has acted on the piston, instead of permitting it to escape into the air.

Q. What is a NON-CONDENSING engine?

A. A non-condensing-engine, *instead of condensing* the steam after it has acted on the piston, *allows it to escape* into the atmosphere.

Q. What is meant by HORSE-POWER?

A. The term horse-power is used by engineers to indicate that mechanical power of a steam-engine which is *equal to the labouring strength of a horse;* thus, if a given amount of work could be accomplished by *ten horses* in a fixed time, and *one steam-engine* could accomplish the same work in the same time, the engine is said to be of *ten-horse* power.

Q. How did this SYSTEM of CALCULATION arise?

A. From the practice of *employing horses* to perform the labour *now* accomplished by *steam*, before the steam-engine was invented.

From repeated experiments, Mr. Watt found that a horse treading a mill path at the rate of 2½ miles per hour, or 220 feet per minute, will, on an average, raise 150 pounds weight by a cord hanging over a pulley, and suspended over a mine shaft; and this labour is equivalent to raising 33,000 pounds weight one foot high per minute. Mr. Watt's steam-engines were constructed so as to work at the rate of 44,000 pounds, raised one foot high, per minute, for each horse power; but in his estimate of their actual effect, he reduced this rate to 33,000 raised one foot per minute for each horse power, considering the difference to be due to their loss of power by friction, and other causes.

Q. What is a LOCOMOTIVE ENGINE?

A. Steam-engines called locomotives, or locomotive-engines, are those which are *worked on a carriage or a railway*, and by transmitting their *motion* to the *wheels*, are moved from place to place.

Q. What is MEANT by STEAM NAVIGATION?

A. The *movement of vessels* on the water *by steam*, instead of oars or sails.

Q. When was STEAM NAVIGATION first introduced?

A. *In the year* 1801, Mr. William Symington made the first experiment in steam-navigation on the Forth and Clyde canals, which ended in the production of the first practicable steam-boat, named the "Charlotte Dundas."

Q. When was the FIRST STEAM-BOAT put in actual operation?

A. *In* 1812, when a steam-boat called the "Comet" began to ply for passengers between Glasgow and Greenock.

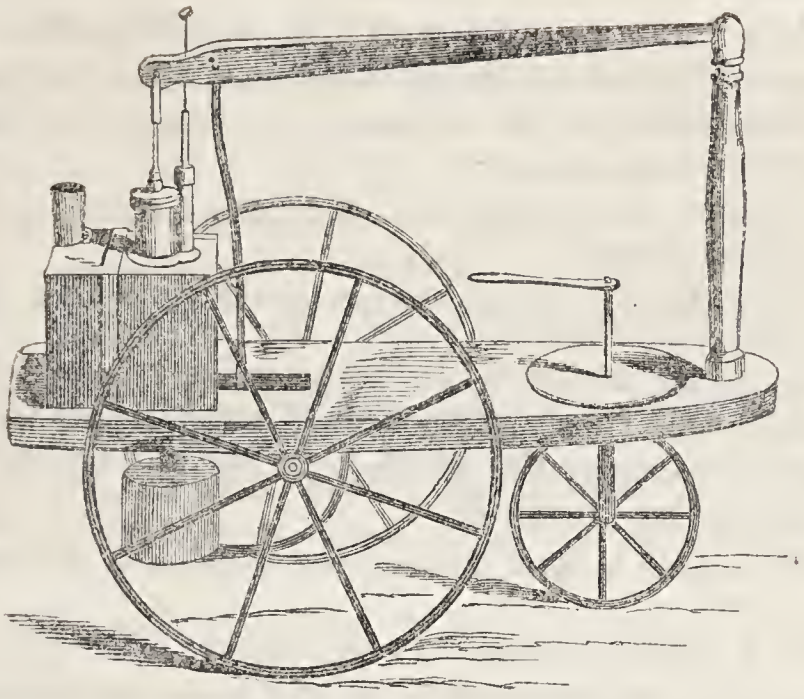
Q. By whom was STEAM NAVIGATION introduced into America?

A. *Mr. Robert Fulton*, who built the steam-boat "Clermont" in 1807, which plied between New York and Albany.

Q. When was STEAM POWER first applied to purposes of travelling on LAND?

A. Experiments were made for this purpose *as early as* 1785, by Mr. William Murdoch, and were tried upon the common roads in Cornwall. His machine is seen in the accompanying engraving.

Fig. 70.



Q. When was the FIRST RAILWAY projected?

A. The Liverpool and Manchester railway was *first projected in* 1823, by Stephenson and others. On the opening of this line the benefits of the railway system became at once apparent.

Q. What is the estimated NUMBER of LOCOMOTIVE ENGINES employed annually in Europe?

A. The *number* of locomotive-engines employed on the various European railways is *estimated at* 7,500; of these 3,700 are employed and 5,000 were made in Great Britain.

Q. What is the estimated DISTANCE travelled by these LOCOMOTIVES every year?

A. *One hundred and twenty millions of miles.*

Q. When did the first steam-vessel cross the Atlantic?

A. The first steam-vessel which crossed the Atlantic was the *American ship Savannah*, from Savannah, Georgia, in 1819.

CHAPTER XXI.

VENTILATION.

Q. What is VENTILATION?

A. The *renewal* of fresh air—a continual *change* of air.

Q. Is the air in a ROOM constantly in motion?

A. Yes; there are always *two currents of air* in the room we occupy; one of *hot* air flowing *out* of the room, and another of *cold* air flowing *into* the room.

Q. How do you KNOW that there are these TWO currents of air in every occupied ROOM?

A. If I hold a lighted candle near the crevice at the *top of the door*, the flame will be blown *outwards* (towards the *hall* or *passage*); but if I hold the candle at the *bottom of the door*, the flame will be blown *inwards* (into the *room.*)

This is not the case if a fire be in the room. When a fire is lighted, an inward current is drawn through *all* the crevices.

Q. Why would the flame be blown OUTWARDS (towards the HALL or PASSAGE) if a candle be held at the TOP of the door?

A. Because the air of the room being heated, and consequently rarefied, *ascends*, and (floating about the upper part of the room) some of it escapes through the crevice at the *top of the door*, producing a current of air *outwards.*

Q. Why would the flame be blown INWARDS (into the ROOM) if the candle be held at the BOTTOM of the door?

A. Because a partial *vacuum* or empty space is made at the *bottom of the room*, as soon as the warm air of the room has ascended to the ceiling or made its escape from the room; and cold air from the hall *rushes under the door* to supply the void.

Q. What is meant by a PARTIAL VACUUM being made at the BOTTOM of the ROOM?

A. A vacuum means a place *from which the air has been taken;* and a "partial vacuum" means a place from which a *part* of the air has been taken away. Thus, when the air near the floor *ascends* to the ceiling, a partial vacuum is made near the *floor.*

Q. And how is the VACUUM FILLED UP again?

A. It is filled up by *colder* air, which rushes (under the *door*, and through the *window* crevices) into the room.

Q. Give me an ILLUSTRATION.

A. If I dip a pail into a pond, and fill it with water, a hole (or vacuum) is made in the pond as *big as the pail;* but the moment I *draw the pail out*, the hole is *filled up* by the water around.

Q. Show how this ILLUSTRATION applies.

A. The heated air which ascends from the bottom of a room is as much taken away as the water in the pail, and (as the void was instantly supplied by *other water in the pond*) so the *void of air is supplied* by the air around.

Q. Why is a ROOM (even without a fire) generally WARMER than the OPEN AIR?

A. Because the air in a room is *not subject to much change*, and soon partakes of the same temperature as our bodies, when it no longer feels cold.

Q. Why do we generally feel COLDER out-of-doors than in-doors?

A. Because the air (which surrounds us) is *always changing;* and as fast as *one* portion of air has become warmer by contact with our body, *another colder portion* surrounds us, to absorb more heat.

Q. Why is there a strong DRAUGHT UNDER the DOOR, and through the crevice on each side, or through the key-hole of the door?

A. Because cold air *rushes from without*, to supply the *void* in the room caused by the escape of warm air up the chimney, &c.

Q. Why is there always a DRAUGHT through the WINDOW crevices?

A. Because the external air (being colder than the air of the room we occupy) rushes through the window crevices, *to supply the deficiency* caused by the escape of warm air up the chimney, &c.

Q. By which means is a ROOM better VENTILATED? by opening the upper or the lower sash?

A. A room is better *ventilated* by opening the *upper sash;* because the hot air (which always ascends towards the ceiling) *can escape more easily.*

Q. Which is the HOTTEST PLACE in a church, chapel, or theatre?

A. The gallery.

Q. How do you ACCOUNT for this?

A. The heated air of the building *ascends;* and all the *cold air keeps near the floor* till it has become heated.

Q. What EFFECT has RAREFACTION upon AIR?

A. It makes it *lighter;* and the lighter it becomes, the higher it rises, as a balloon rises in the common atmosphere, or a piece of cork rises in water.

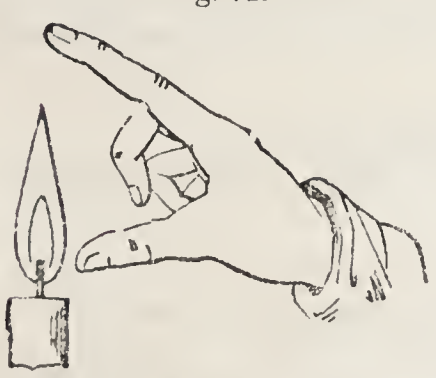
Q. Does HOT AIR always rise?

A. Yes; and therefore the *stoves* should be fixed as near the *floor* as possible, in order that they may properly heat the room.

Q. What MEANS are usually employed to HEAT apartments?

A. *Open fire-places* are commonly employed; but rooms are sometimes heated by hot air, by steam, or by hot water.

Fig. 71.



The method of heating by common fires may be understood by reference to the accompanying diagram. Here we see that we can hold the finger or thumb at a short distance from the flame of a candle without experiencing any inconvenience; but when we hold the finger above the flame, we are forced, by the increased intensity of heat in that direction, to remove it to a greater distance. An ordinary fire in a common stove, or open grate, is precisely the same in principle as the flame of a candle. The lesser amount of heat is thrown out in the front, while the greater amount of heat escapes at the top. We thus learn that by the usual method of heating rooms great waste of heat is occasioned, *the heat ascends the chimney instead of warming the room.*

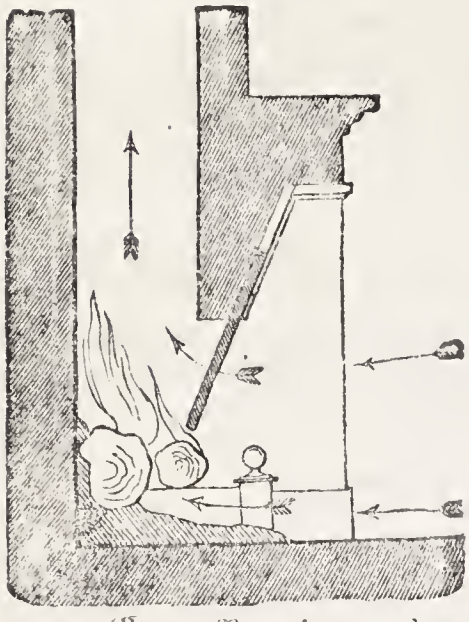
Q. What connection is there between WARMING and VENTILATING?

A. A fire cannot be made to burn *without air;* the heat of the fire sets the air in motion. What is meant by ventilation, is a *change of air;* there is, consequently, a close connection between warming and ventilating.

Q. Is the AIR drawn TOWARDS the FIRE?

A. Yes; the mass of cold air in the apartment is immediately drawn towards the fire.

Fig. 72.



[The annexed diagram shows a section of a common stove. The direction of the air is indicated by the arrows.]

Q. What is meant by the DRAUGHT of a CHIMNEY?

A. By the draught of a chimney is meant an upward current, which is caused by the fire in the grate. When this current is rapid, we say the chimney *draws* well.

Q. What is SMOKE?

A. Minute particles of *carbon*, separated from the fuel, but not consumed.

Q. What occasions the SMOKE to CURL as it goes up the chimney?

A. The effect is produced by the ascending and descending currents of air, which oblige it to assume that form by driving it round and round.

Q. Why does the SMOKE go up the CHIMNEY?

A. It is carried up the chimney by the *air*, which is heated by the fire, and thus made to ascend.

Q. What is meant by a SMOKY CHIMNEY?

A. A chimney from which the smoke, instead of passing out into the air above, rushes out into the room.

Q. How is this OCCASIONED?

A. By the *currents of air* from above, which, descending the chimney, drive the smoke into the room.

Q. What is the CAUSE of this?

A. It arises from the fact that *fresh air* is not supplied as rapidly as it is consumed by the fire; the result is, that the air rushes in from above to supply the deficiency.

Q. Why do we OPEN the DOOR or WINDOW when a CHIMNEY SMOKES?

A. To supply the fire with a fresh current of air, and thus enable the smoke to ascend the chimney.

Q. What is the FUNNEL or FLUE of a chimney?

A. The part of the chimney through which the smoke ascends.

Q. Is a LONG or SHORT FLUE the best?

A. A long flue.

Q. Why does a CHIMNEY SMOKE if the FUNNEL be very SHORT?

A. Because the *draught* of a short flue is *too slack* to carry the smoke up the chimney.

Q. Why is the DRAUGHT of a SHORT FLUE more SLACK than that of a long one?

A. 1. Because the *fire is always dull and sluggish* if the chimney be too short;

2. Because the smoke rolls *out* of the chimney before it has acquired its *full velocity* or *speed;* and

3. Because the wind, rain, and air have more influence over a *short* funnel than over a *long* one.

Q. Why is the FIRE always DULL and SLUGGISH if the CHIMNEY-FLUE be very SHORT?

A. Because the draught is bad; and as the rarefied air *passes very tardily up the chimney, fresh air* flows as tardily *towards the fire*, to supply it with *oxygen.*

Q. Why does not SMOKE acquire its full VELOCITY in a SHORT funnel?

A. Because the higher smoke ascends, for a limited distance (provided the fire be clear and hot, and the flue be unobstructed), the *faster* it goes; if, therefore, *a funnel be very short*, the smoke never acquires its full velocity.

Q. Does the DRAUGHT of a chimney depend on the SPEED of the SMOKE through the flue?

A. Yes; the more quickly *hot* air flies *up the chimney*, the more quickly *cold air* will rush *towards the fire* to supply the place; and therefore the *longer the flue*, the *greater the draught.*

Q. Why are the CHIMNEYS of MANUFACTORIES made so very LONG?

A. To increase the *intensity* of the fire. Because the *draught* being greater, more fuel is consumed in the same time, and, of course, the *intensity* of the heat increased.

Q. Why do BLOWERS, when placed before a grate, tend to KINDLE the FIRE?

A. Because the air (by passing through the fire) is made much hotter, and ascends the chimney more rapidly: and because the blower increases the draught; and the faster the *hot air flies up* the chimney, the faster will *cold air* rush *towards the fire.*

Q. If TWO FIRES are burning in one close room, the apartment is filled with SMOKE: why is this?

A. One or other of the two fires will *exhaust the most air*, and the remaining fire will smoke from the *want* of a *sufficient quantity.*

Q. What is a COWL?

A. A kind of *hood*, fixed on the top of a chimney-pot, and which, turning like a weather-cock, constantly presents its back to the wind.

Q. What PURPOSE does it answer?

A. It is intended to *prevent the wind descending the flue*, and thus making the chimney smoke, but it is not a perfect remedy.

Q. What is the BEST remedy to PREVENT a chimney SMOKING?

A. To carry the *flue higher* than any surrounding building.

Q. Do not chimneys SMOKE when they require SWEEPING?

A. Yes; as the soot accumulated in the flue *prevents* the *free escape* of the smoke.

Q. Besides the ORDINARY stoves, what OTHER means are employed for heating rooms ?

A. *Hot air* is sometimes employed for this purpose; *steam* is also used, and *hot water*.

Q. How is HOT AIR employed in heating rooms ?

A. The common air being heated by a *calorifer*, or *hot-air stove*, is conveyed through metallic pipes, and is thus made to heat any room or rooms which may be desired.

Q. How is STEAM employed for this purpose ?

A. The steam, being produced in a boiler, is *driven through pipes*, and thus conveyed to the room or rooms which are to be heated.

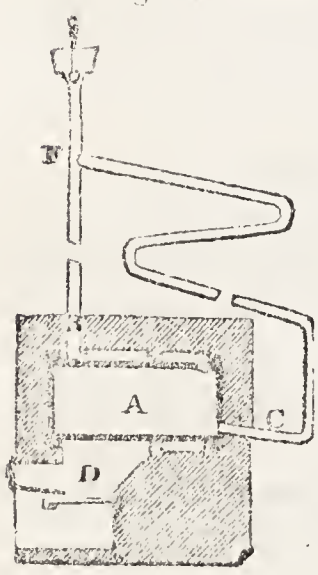
Q. Is not the plan of heating apartments by HOT WATER of ancient date ?

A. Yes; the practice of heating houses by hot water was *practised by the Romans*.

Q. What SYSTEM is NOW adopted ?

A. *Water*, being heated in a boiler, is *transmitted through a series of pipes*, brought back again to the boiler, and so kept constantly in *circulation*.

Fig. 73.



The diagram represents the plan of heating by the circulation of hot water. From the top of the boiler A, placed on a fire D, rises an upright tube F. The hot water ascends towards F; but at F is commenced a series of pipes through which the water passes, and successively heats the different parts of the building. During this passage it is cooled, and returns to the boiler at C, when it enters at the bottom; and thus a continued circulation is kept up in the direction A F C.

Q. Which would prove the warmest upon a bed—a BLANKET or an oiled silk or India-rubber AIR-TIGHT covering ?

A. The *air-tight* covering.

Q. Why do we not USE oiled silk or India-rubber bed-coverings in the winter ?

A. Because they *prevent ventilation*, and, by shutting in the insensible perspiration, soon produce *dampness*.

Q. Is there a CIRCULATION of the air through the bed-coverings at night ?

A. Yes; from every part of the bed-clothes immediately over the person there is a *constant outward oozing* of warm air, and an oozing inwards of cold air in lower situations around.

Q. What TEMPERATURE is most proper for keeping an apartment in a healthy and pleasant condition during the cold season ?

A. From 60° to 65° F., with a *free ventilation*.

Q. At what PERIOD were chimneys first used in England ?

A. Not before the middle of the fourteenth century; and in the *time of Queen Elizabeth* they were considered as luxuries for the wealthy, and not necessities.

CHAPTER XXII.

SOLUTION AND CRYSTALLISATION.

Q. When SALT is mixed with water and DISAPPEARS in the liquid, what is said to have taken place?

A. The salt is said to have *dissolved* in the water, and the liquid is now a *solution of salt.*

Q. What, then, is a SOLUTION?

A. A solution is the result of a combination between a solid and a fluid; and when a solid disappears in a liquid, if the compound exhibits *perfect transparency*, we have an example of a *perfect solution.*

Q. When is a solution said to be SATURATED?

A. When the fluid has dissolved as much of the solid as it is capable of doing, it is said to be *saturated;* or, in other words, the affinity of the fluid for the solid, that is, the power which inclines it to unite, continues to operate to a certain point, where it is overbalanced by the solid; it then ceases, and the fluid is said to be *saturated.*

Q. What is the difference between a SOLUTION and a MIXTURE?

A. A solution is a *chemical union;* a mixture is a mere *mechanical union* of bodies.

Q. Why will WATER dissolve SUGAR?

A. Because there is *attraction* or *affinity* between the particles of the water and the particles of the sugar.

Q. Why will not WATER dissolve GRANITE or METALLIC iron?

A. Because there is not *sufficient affinity* or *attraction* between the particles of the water and those of the iron or granite.

Q. Are there ANY LIQUIDS that have sufficient affinity to dissolve iron and granite?

A. Yes; certain *acids* have so great an affinity for the iron and granite that they are enabled to dissolve them.

Q. Why will not WATER dissolve OIL?

A. Because there is *no affinity* or attraction between the *particles* of the two substances.

Q. Why will ALCOHOL and ETHER dissolve oil?

A. Because the *attraction* or *affinity* between the alcohol or ether and the oil is sufficient to enable them to effect a solution.

Q. What EFFECT has heat upon the dissolving power of liquids?

A. In most cases the addition of *heat* to a liquid greatly increases its *solvent properties. Hot water* will dissolve much more sugar than cold water, and hot water will also dissolve many things which cold water is unable to affect.

Q. Why does a PIECE of SUGAR (held in a spoon at the TOP of our tea) melt very RAPIDLY?

A. Because as the tea becomes *sweetened*, it *descends to the bottom of the cup* by its own gravity, and *fresh* portions of unsweetened tea are brought constantly into contact with the sugar, till the lump is entirely dissolved.

Q. Why does the LUMP of SUGAR MELT more QUICKLY when STIRRED ABOUT?

A. Because *fresh portions of unsaturated tea* come in contact with the lump, and soon dissolve it.

Q. Why is a LUMP of SUGAR (left at the bottom of a cup) SO LONG in MELTING?

A. Because (as it melts) it makes the tea above it *heavier*, and (so long as it remains at the bottom) is surrounded by tea fully *saturated* with sugar; in consequence of which the *same* portions of liquid will hold *no more sugar in solution.*

Q. Why does a WET SPONGE CLEAN A SLATE?

A. Because the water holds in solution the pencil-marks made on the slate; and the mechanical friction employed in wiping the slate detaches the particles of pencil-dust.

Q. What is SPONGE?

A. A well known substance, produced by very small animals which live in the sea; these animals are called polypi by naturalists.

Q. What do we mean by AFFINITY?

A. Affinity is that kind of attraction by virtue of which bodies of a *dissimilar nature* combine together into a whole, which appears *perfectly uniform* to the senses, even when assisted by the most powerful optical instruments.

Q. If we evaporate some spring water in a vessel, the bottom of the vessel will generally be found to contain some EARTHY MATTER: why is this?

A. The spring water, as it comes through the ground, *dissolves* and *retains* some substances, which it leaves upon the bottom of the vessel when it is evaporated.

Q. How is SALT formed from sea-water?

A. The sea-water containing salt is collected in *large vats* or pans, and the water evaporated either by the heat of the sun or by fire. As the water *evaporates*, the salt is left in the vessel.

Q. How MUCH SALT does a POUND of sea-water contain dissolved in it?

A. From *one-half to five-eighths of an ounce.*

Q. As heat enables liquids to dissolve and hold in solution a greater quantity of soluble substances than the same liquid is enabled to do when it is cold, what takes place when a HOT SATURATED SOLUTION is COOLED DOWN?

A. A part of the substance held in solution will be *thrown down* from the liquid and *deposited.*

Q. How much more SALTPETRE is boiling water enabled to retain than water having a temperature of only 32° F.?

A. *One hundred parts* of water at 32° will dissolve only *seven parts of saltpetre;* the same quantity of boiling water will dissolve *three hundred and thirty-five parts.*

Q. When a substance is thrown down from a solution, either by COOLING or EVAPORATION, in what MANNER is it deposited?

A. The particles sometimes join in an indiscriminate manner, and give rise to irregular, shapeless masses; but more frequently they attach themselves to each other in a certain order, so as to constitute solids possessed of a *symmetrical form.*

Q. When the substance deposited has no PARTICULAR SHAPE, what is it called?

A. *Amorphous;* that is, without form.

Q. When it has a REGULAR, SYMMETRICAL SHAPE, what is it called?

A. *Crystallised* or *crystalline.*

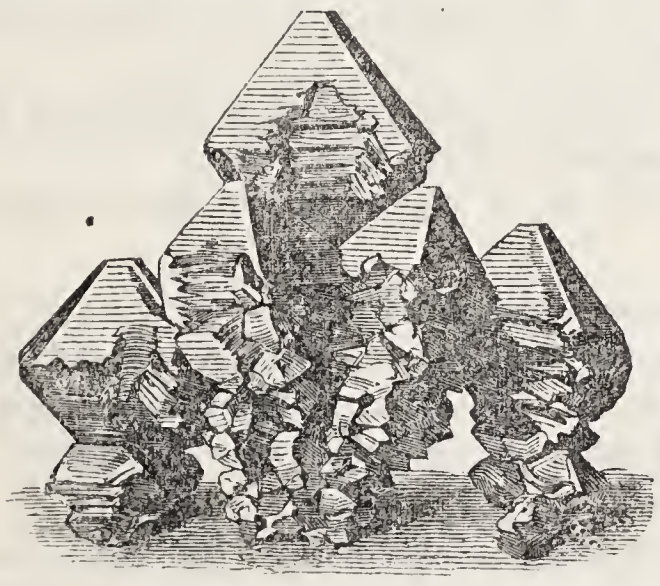
Q. What is CRYSTALLISATION?

A. Crystallisation is the effect of *attraction among the atoms* or particles of substances regulated by certain laws, according to which atoms of the same kind of matter unite in regular forms.

Q. How is this FACT shown by EXPERIMENT?

A. If we dissolve a piece of alum in pure water, the *mutual attractions* of the particles are *destroyed* by the water; but if the water be *evaporated*, they *unite*, and form in uniting eight-sided figures called *octahedrons.* *Fig.* 74 represents crystals of alum.

Fig. 74.



Q. Are most MINERALS and EARTHY substances capable of crystallisation?

A. Yes; under favourable circumstances.

Q. What CIRCUMSTANCES FAVOUR crystallisation?

A. When a fluid is *slowly changing into a solid*, the arrangement of the particles being at the same time undisturbed by motion.

Q. Are there many FORMS of crystals?

A. The number of crystalline forms amounts to *several thousands.*

Q. Does the SAME COMPOSITION always crystallise in the same FORMS?

A. Yes; *unless the conditions of the crystallising body are altered.* In accordance with this fact, we are often enabled to distinguish and pronounce upon the composition of a body merely from the form of

its crystals, as the same body, *under the same circumstances*, always crystallises in the same manner.

Q. Explain, by EXAMPLE, the manner of distinguishing a substance by the form of its crystals?

A. For example: fluor-spar always crystallise in cubes, and quartz in six-sided pyramids. These minerals, so far as *colour* and *lustre* are concerned, often closely resemble each other, but their forms are peculiar to them.

Q. What is the well-known "ROCK," or "SUGAR-CANDY?"

A. Simply *sugar* suffered to *crystallise* under favourable conditions.

Q. What is the so-called "LOAF-SUGAR?"

A. In the formation of "loaf-sugar," the process of crystallisation is *hastened* or *disturbed* in such a manner that it commences at a *myriad of points* at the *same instant*, and neither time nor space is allowed for the particles to expand to a large size and regular outline. Nevertheless, if we examine a small particle of loaf-sugar through a magnifying-glass, we shall find that it is distinctly crystallised.

Q. In what STATE is the sugar which is contained in molasses?

A. Owing to a chemical change which takes place in the syrup during the process of manufacture, the sugar contained in molasses is *uncrystallisable.*

Q. Why, when we boil down molasses to make molasses-candy, do we always obtain a STICKY, GUM-LIKE sugar, and NOT a DRY, HARD sugar?

A. Because the sugar contained in the molasses is *incapable of crystallising.*

Q. How will you DEFINE a crystal?

A. The *geometrical form* possessed by a vast number of mineral and saline substances, whose particles combine with one another by the attraction of cohesion, according to certain laws.

Q. What are the ELEMENTS of a crystal?

A. Every perfect crystal is bounded by *plane surfaces*, which are called its *faces.* The straight line formed by the intersection of two faces is called an *edge;* the meeting of three or more edges in a point forms a *solid angle.*

Thus, in the octahedron, fig. 75, the bounding planes are the faces, the lines formed by their intersection the edges, the meeting of four of which in the same point produces a solid angle of the crystal.

Q. Into what TWO CLASSES are crystals divided?

A. Into *simple* and *compound.*

Q. What are SIMPLE crystals?

A. A simple crystal has all its *faces equal* and *similar* to each other. Thus *figs.* 75, 76, and 77 represent simple forms, *fig.* 75 being an *octahedron* bounded by eight faces, each of which is an

equilateral triangle; *fig.* 76, a cube bounded by six squares; while *fig.* 77 has for its faces twelve equal and similar rhombs.

Fig. 75.

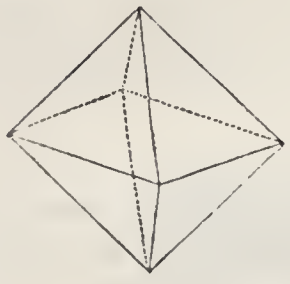


Fig. 76.

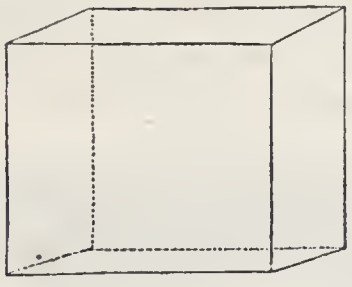
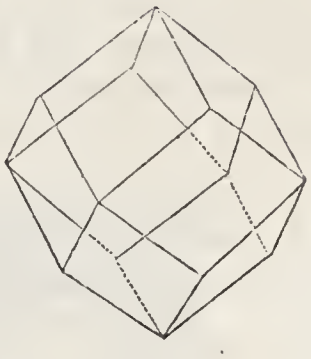


Fig. 77



Q. What is a COMPOUND crystal?

A. A compound crystal is bounded by at least *two different classes of faces*. *Figs.* 78, 79, and 80 represent forms and varieties of compound crystals.

Fig. 78.

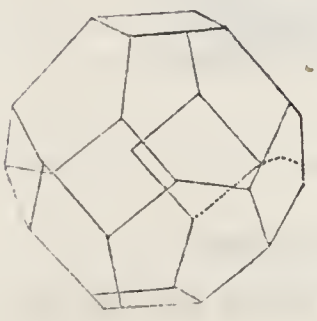


Fig. 79.

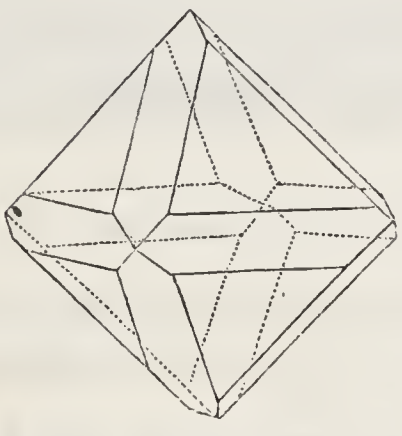
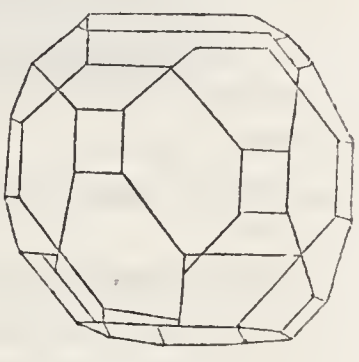


Fig. 80.



Q. How may two substances, dissolved together in water, be SEPARATED from each other by CRYSTALLISATION?

A. If we dissolve salt and saltpetre together in warm water, and then suffer the liquid to evaporate, the two salts which are intimately united in the solution will, *upon crystallisation*, *separate completely from each other*. The *saltpetre* separates into *long prisms*, containing no trace of common salt, and the latter separates into *cubes*, entirely free from saltpetre.

Q. Why did this SEPARATION of the two substances take place?

A. In accordance with the laws of crystallisation, which compelled each substance in crystallising to *arrange its particles in a determinate and regular form*, different from the other.

Q. Why do the figures of crystals VARY in regularity?

Because their regularity is influenced by the *rapidity* with which the liquid from which they are deposited evaporates: thus, if the process be slowly conducted, the particles unite with *great regularity*; if hurried, the crystals are irregular and confused. To obtain very *regular crystals*, the evaporation must be *spontaneous*, or that which takes place at common temperatures.

Q. Why has strong salt and water a FILM or PELLICLE upon its surface?

A. Because the *attraction* of the *saline particles* for each other is becoming *superior* to their attraction for the water.

Q. Why will not salt CRYSTALLISE when dissolved in a considerable quantity of water?

A. Because the particles of the salt are too *far asunder* to exert reciprocal attraction; in other words, they are more powerfully attracted by the water than by each other.

Q. Why does salt crystallise upon EVAPORATION of part of the water?

A. Because some of the saline particles then gradually *approach each other*, and, according to the laws of crystallisation, form regular solids. Another portion of the salt will remain dissolved in the water which is left; this is usually called the *mother liquor*.

Q. Why do many chemical compounds (salts) when exposed to the air EFFLORESCE, or fall to powder?

A. Because they lose their *water of crystallisation;* or, in other words, the water which they incorporate into their structure on assuming the crystalline form.

Q. Why do some chemical compounds (salts) EFFLORESCE more than others?

A. Because some salts thus completely *lose* their water of crystallisation, while others *retain* different quantities, according to the dryness of the air.

Q. Why do some salts DELIQUESCE (or become moist or liquid) by exposure to the atmosphere?

A. Because they *attract moisture* from the atmosphere.

Q. If two substances differently soluble in water are mixed together, how can they be PURIFIED and SEPARATED one from another?

A. If a hot saturated solution of the mixed substances be made, and then suffered to cool, that substance which is *least soluble* in water, or the one for which the water has the *least affinity*, will *crystallise out* and be *deposited first*, while the other substance, which is more soluble, will remain in solution, and may be drawn off, leaving the one first deposited tolerably pure. In this way saltpetre is refined from salt and other ingredients that may be mixed with it.

Q. Does water in FREEZING CRYSTALLISE?

A. Always.

Q. What is the cause of the pretty FROSTWORK seen on bedroom WINDOWS in winter-time?

A. The *breath* and insensible *perspiration* of the sleeper (coming in contact with the ice-cold window) are *frozen* by the cold glass, and, crystallising, form those beautiful appearances seen on a winter morning.

Q. Are all the figures of frostwork formed in accordance with certain FIXED LAWS?

A. All these figures are *limited by certain laws*, and the lines which bound them form among themselves no angles but those of 30°, 60°, and 120°.

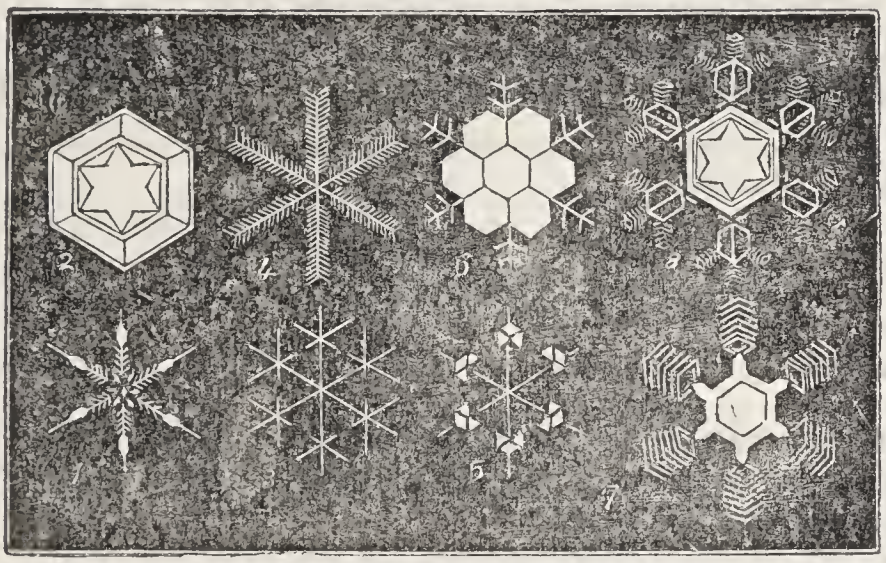
Q. If you fracture thin ice by allowing a pole or WEIGHT to fall upon it, will the lines of the fracture have anything of REGULARITY?

A. Yes; the fracture will generally present a *star* with *six points equally distant* or at angles of 60°.

Q. In what SUBSTANCE are the crystals of frozen water seen to the best advantage?

A. On *snow*, under the microscope. *Fig.* 81 illustrates the varied and beautiful forms of snow crystals.

Fig. 81.



Q. Is much TIME required for the formation of large crystals?

A. Yes; many of the large crystals dug from the earth have undoubtedly required *many years* for their formation.

A crystal of quartz at Milan, in Italy, is three feet and a quarter long, five feet and a half in circumference, and weighs 870 pounds. Crystals of beryl have been found in New Hampshire that weigh over a ton.

Q. Is the formation of crystals accompanied with a DEVELOPMENT of heat?

A. Yes; heat is always *liberated* when a liquid passes into a solid state. If the crystallisation is *rapid*, heat is rapidly produced; and in some instances crystallisation is attended with the *evolution of light*.

Q. Does a substance occupy MORE SPACE when crystallised than when dissolved?

A. Most substances in crystallising *expand*, and occupy an enlarged space.

Q. What beautiful practical application has been made of this EXPANSIVE PROPERTY of crystallising substances?

A. Some fibres which are closely adherent to each other, are soaked in a saturated solution of an easily crystallisable substance, and then suffered to dry. The salt contained in the solution penetrates every part of the fibre with the liquid, and, as it *dries*, *crystallises and expands*. In this way the fibres are broken up, and forced apart from each other.

Q. How has crystallisation been taken advantage of for SEPARATING SILVER from LEAD in MINING?

A. Much of the lead mined from the earth contains silver, and the silver being of value only when separated from the lead, the following method of parting them has been devised: the two metals are *melted*

and suffered to *cool slowly;* the silver, forming into crystals more easily than the lead, *crystallises* first, when the lead left behind is *poured off.*

Q. When iron is subject to long-continued vibration, what CHANGE takes place in its composition and character?

A. Wrought iron has essentially a *fibrous character*, which gives it toughness and strength; but when subjected to long-continued vibration, especially under pressure, its tough, fibrous character becomes changed into a coarse, crystalline one. That is, certain of the fine crystalline grains become enlarged at the expense of others, and thus its cohesive force (power of sticking together) is diminished.

Q. What is the CONDITION of iron when it first comes from the furnace, and changes from a liquid to a solid state?

A. Its outermost particles, by a species of attraction, *form crystals*, and these crystals, drawn together by a like attraction among each other, constitute the entire mass.

Q. If you examine a piece of cast iron with a microscope, what APPEARANCE will it present?

A. It will be seen to be made up of a *mass of crystals*, each crystal having a *regular form*, and that the aggregation of the whole constitutes the mass of the metal.

Q. How is cast iron converted into WROUGHT IRON?

A. The iron is freed in a great measure from the *carbon** that is combined with it, and then subjected to blows of the hammer, and rolled between rollers, which elongate it.

Q. What EFFECT does this treatment have?

A. By thus working it, each of the crystals is *gradually elongated* into a thread, so that wrought iron is an aggregation of fibres (fibrous iron, as it is sometimes called), or a series of threads kept together by the attraction of cohesion.

Q. What takes place when a bar of fibrous or wrought iron is made to VIBRATE by SHOCKS, either by the blow of a hammer, or by the rapping of any part of the machine, or by the continued rolling and striking of a railway car-wheel upon the rails?

A. The little fine threads or fibres *snap one by one*, until the whole becomes a mass of crystals, and the metal loses its tenacity, and has to be recast or rewrought, before the aggregation of the particles can be restored.

Q. Why should all concussions and SUDDEN JARS in machinery be avoided as much as possible?

A. Because any one blow given on one part of a machine of metal must more or less *vibrate* through the connections to the other parts; and every shock which a piece of mechanism receives causes the ultimate particles to *move upon each other.*

Q. How was this curious fact FIRST DISCOVERED?

A. An accident having occurred on a railroad in France by the breaking of an axle, by which many lives were lost, the attention of scientific men was called to the fact that the pieces of iron composing

* *Carbon* is pure charcoal.

the axle when *first used* were *strong* and capable of standing a test, but after use for a definite period, could be broken by a force far inferior to that by which they had been tested; many imaginary ideas were formed to account for this phenomenon, when, finally, one person took a series of rods about the size of pipestems, and with great patience allowed them to fall for hours and hours upon an anvil, producing rapid strokes and vibrations. After subjecting them for a long time to this treatment, he found that the rods could be snapped and broken as a pipestem of the same dimensions.

Q. Some years since a large wrought-iron cannon exploded on board the United States ship Princeton, killing a number of distinguished men: what was supposed to be the CAUSE of the explosion?

A. The continued *vibration of the particles of the iron*, caused by the heavy explosions, changed its nature from a fibrous to a crystalline character, and so weakened the cannon, that it finally burst.

Q. Are all large iron cannon LIABLE to EXPLODE after they have been fired a certain number of times?

A. *Yes;* and, for this reason, a cannon which has been long in use, though apparently sound, is always condemned and *broken up*.

Q. Why are AXLES of railway carriages apt to BREAK after long-continued use?

A. Because the *continued vibration* and *strain* upon the particles of iron of which they are composed, changes it from a fibrous to a crystalline structure, and thus weakens it.

Q. Would a railway axle be almost CERTAIN to break from this cause after long-continued use?

A. It is generally considered that they *are certain to fracture* from this cause after a sufficient lapse of time and use.

Q. How may very LARGE and PERFECT crystals of an easily crystallisable substance be FORMED?

A. By repeatedly transferring a crystal from one *saline solution to another* of the same salt a little more concentrated, and evaporating at very moderate temperatures, or even spontaneously at common temperatures.

Q. In jewellery, are the SMALL GEMS generally more PERFECT and valuable than the large ones?

A. The most perfect crystals of gems met with in nature are only of a *moderate size*. The larger ones are less clear, and even opaque, and the faces lose their smoothness, and much of their lustre.

Emeralds sufficiently pure for jewellery do not often average half an inch in length, and seldom so much as this?

Q. Do some crystalline solids slowly change their internal structure SPONTANEOUSLY?

A. *They do;* thus sugar, which has been rapidly boiled down to a solid consistence, as in barley-sugar, is at first transparent, broken with difficulty, and presents a glassy fracture. After a short time it becomes *opaque* and *almost friable*.

Q. How does BRASS WIRE change?

A. Brass wire, when first manufactured, is strong and tenacious, but when exposed to *damp air*, or the *fumes of an acid*, becomes brittle.

Q. What very CURIOUS CHANGE takes place with the crystals of iodide of mercury ?

A. When they are first formed, they are of a bright *red colour*, but if scratched with a hard substance, as the point of a pin, the crystals turn over, or readjust themselves, and become *bright yellow.*

Fig. 82.

Q. In what form do some of the varieties of IRON ORE crystallise ?

A. The sulphuret of iron, so often mistaken for *gold*, crystallises very beautifully in *cubes*, which gold never does. (*See fig.* 82.)

Q. Does LIGHT appear to influence crystallisation ?

A. Light has a *powerful influence* over the crystallisation of certain substances. Thus, in druggists' shops, the camphor contained in glass jars is arranged in beautiful crystals upon the side next to the light.

Q. What is meant by "ANNEALING ?"

A. Annealing is the process of *softening* and *restoring* the *malleability of metals* and the softness of glass, by heating them, and allowing them to cool very slowly. It consists in placing the articles while hot in an oven, where they are allowed to cool gradually.

Q. If glass is allowed to COOL VERY QUICKLY, what is the result ?

A. It is *very brittle*, and breaks with the *slightest blow ;* whereas if it is allowed to cool slowly, its particles arrange themselves in such a way as to form a *fibrous texture*, elastic, and not easily broken.

Q. How are iron and steel HARDENED ?

A. By cooling them *very rapidly* after heating.

Q. How are iron and steel made SOFT ?

A. By cooling them *very slowly* after heating.

Q. The hooked top of walking-sticks is made by BOILING the end of the stick, and then bending it into an arch : why is a stick made FLEXIBLE by BOILING ?

A. Wood contains many substances *soluble* in hot water, as starch, gum, &c., and several others which are *softened* by it ; as, therefore, several substances are *dissolved* and others *softened* by boiling water, the *stick* is rendered flexible.

Q. If you scrape a slip of paper with a knife, why will the paper CURL ?

A. Because the surface of the paper is *contracted* by scraping, which brings the particles closer together ; this contraction of the surface bends the slip of paper into a curl or arch.

Q. If a crystal of alum, for example, is broken into fragments, and the fragments placed in a saturated solution, what TAKES PLACE ?

A. Each fragment *reproduces* the *form* of the crystal from whence it was broken.

Q. Have chemists been able to reproduce in their laboratories crystals of GEMS and other PRECIOUS STONES?

A. In *some instances* they have been enabled to reproduce them most *successfully*.

Q. In what MANNER has it been accomplished?

A. Sometimes through the agency of *electricity*, but generally by mixing the matter which enters into their composition, and submitting them to the long-continued action of *intense heat*. In this way crystals of the *topaz*, *sapphire*, *garnet*, and *ruby* have been produced of great beauty.

METEOROLOGY.

CHAPTER XXIII.

THE ATMOSPHERE.

Q. What is METEOROLOGY?

A. Meteorology is that branch of natural science which treats of the *atmosphere* and its *phenomena*.

Q. What is the ATMOSPHERE?

A. *A thin fluid* which surrounds the earth on every side, and goes with it throughout both its daily and annual revolutions.

Q. Of WHAT is the ATMOSPHERE composed?

A. It is composed principally of two different sorts of gases—one termed *oxygen*, and the other *nitrogen*.

An aqueous (watery) vapour is also present in the atmosphere, and about ten parts of carbonic acid gas to every ten thousand parts of atmospheric air?

Q. In what PROPORTION are oxygen and hydrogen present in the atmosphere?

A. If we represent the atmosphere at 100, oxygen would be 21, and nitrogen 79; that is, one part oxygen, and four parts nitrogen.

Q. What is MEANT by a GAS?

A. An *elastic fluid*, usually invisible and without colour, like common air.

Q. How is the air HEATED?

A. In two ways: first, by the luminous *beams* of the *sun;* secondly, by the *radiation* and *conduction* of heat from the earth.

Q. In what manner is the air heated by RADIATION from the earth?

A. By *convection;* thus, the *sun* heats the *earth*, and the *earth* heats the *air resting upon it;* the air thus heated *rises*, and is succeeded by *other air*, which is heated in a similar way, till the whole volume is *warmed* by "convective currents."

Q. What is meant by "CONVECTIVE CURRENTS" of hot air?

A. Streams of air heated by the earth, which *rise upwards*, and *carry heat with them.*

Q. How is the AIR made COLD?

A. The air resting on the earth is made *cold* by *contact;* this cold air makes the *air above it cold;* and cold currents (or winds) cause the whole to mix together, until all becomes of one temperature.

Q. What EFFECT is produced upon AIR by COLD?

A. It is *condensed* or compacted into a smaller compass; in consequence of which *it becomes heavier*, and descends towards the ground.

Q. Prove that air is condensed by COLD?

A. Lay a bladder half full of air before a fire till it has become *inflated;* if it be now removed *from* the fire, the bladder will *collapse* again, because the air condenses into its former bulk.

Q. What effect has HEAT upon the AIR?

A. Heat *rarefies* the air, and causes it to expand.

Q. What is meant by the MEAN DAILY TEMPERATURE?

A. The mean or average temperature of the day is found by observing the thermometer at fixed intervals of time during the twenty-four hours, and then *dividing the sum of the temperatures* by the *number of observations.*

Q. How is the mean ANNUAL temperature of a particular point ascertained?

A. By taking the average of all the *mean daily temperatures throughout the year.*

Q. How does temperature VARY with the LATITUDE?

A. The average annual temperature of the atmosphere *diminishes* from the *equator towards either pole.*

Q. Give EXAMPLES of this variation.

A. At the equator, in Brazil, the average annual temperature is 84° F.; at Calcutta, lat. 22° 35′ N., the annual temperature is 82° F.; at Savannah, lat. 32° 5′ N., the annual temperature is 65° F.; at London, lat. 51° 31′ N., the annual temperature is 50° F.; at Melville Island, lat. 74° 47′ N., the mean annual temperature is 1° below zero.

Q. How does the temperature VARY with the ALTITUDE above the earth's surface?

A. Temperature *diminishes with the altitude.* As a general rule, a loss of heat occurs to the extent of 1° F. for every 343 feet of elevation.

Q. How does the gradual reduction of temperature as we ascend from the surface of the earth affect the MOISTURE of the air?

A. In every latitude there is a *point above the surface* of the earth where moisture, once frozen, *always remains congealed.*

Q. Why are the TOPS of very high mountains always covered with PERPETUAL SNOW?

A. Because, at the great elevation of their summit, the *temperature* of the atmosphere is so *low* that the congealed moisture which falls upon them never melts.

Q. What is a GLACIER?

A. The glacier only exists upon mountains whose summits are covered with perpetual snow. The snow upon the higher parts becomes somewhat softened during the summer, and in the winter is again hardened nearly to ice. In the succeeding summer, the action of the sun, and the internal heat of the earth, detach large masses loaded with recently deposited snow into the neighbouring valleys, where, being accumulated, and the crevices filled with snow or water, which at last *hardens to ice*, they form huge seas of ice, or *glaciers;* in French, *mers-de-glace.*

Q. Do the glaciers continue to INCREASE YEAR by YEAR?

A. Very many of them do; and in Switzerland many valleys, once *fertile*, are now *filled with glaciers.* From the bottom of the glacier streams of water constantly issue, and it is from such sources that the rivers *Rhine* and *Rhone* of Europe *take their rise.*

Q. How are the gigantic icebergs FORMED which are found floating at some seasons in the Atlantic?

A. They are portions of *great glaciers* formed in the northern regions, which become *detached* and float in the sea.

Q. How HIGH are icebergs sometimes seen?

A. Sometimes exceeding 300 *feet in height.*

Q. At what ELEVATION above the surface of the earth, at the EQUATOR, will water remain frozen?

A. At an elevation of about 15,000 feet.

Q. At what ELEVATION in the STRAITS of MAGELLAN will water remain frozen?

A. At about 4,000 *feet.*

Q. What is the POINT where water remains frozen CALLED?

A. The line of *perpetual snow.*

Q. Why are not all places which lie under the same parallel of latitude of the SAME TEMPERATURE?

A. Because various *disturbing circumstances* tend to *vary* the mean temperature.

Q. What DISTURBING CIRCUMSTANCES affect the temperature of particular situations?

A. 1. The geographical position of the country.
2. Its elevation above the level of the sea.
3. Its nearness to or distance from the sea.
4. The slope or inclined plane which it presents.
5. The position of mountain chains.
6. The nature of the soil.
7. The degree of cultivation which the soil has received.
8. The prevalent winds.
9. The annual quantity of rain that falls.

Q. How does the GEOGRAPHICAL POSITION of a country affect its CLIMATE?

A. On account of the heat experienced from the sun's rays. In some countries the heat is much more intense than in others. Africa is always a hot climate; Greenland always cold.

Q. How does the elevation of LAND above the SEA LEVEL affect its temperature?

A. The higher we rise, the colder the air becomes; consequently, lands considerably elevated above the sea level, are colder than those in lower regions.

Q. What EFFECT on climate has NEARNESS to, or REMOTENESS from, the sea?

In cold climates the sea lessens the cold; in warm climates the sea diminishes the heat.

Q. How does the SLOPE of a country affect its climate?

A. By exposing it more or less to the direct rays of the sun.

Q. What EFFECTS have MOUNTAINS on climate?

A. Chains of mountains afford shelter from the winds, and thereby augment the temperature; mountains, however, which intercept south or west winds, lower the temperature, because these winds are warm.

Q. What EFFECT has the nature of the SOIL on climate?

A. One soil acquires heat, keeps its acquired heat, or gives it forth in radiation more rapidly than another. All varieties of soil have different powers of radiation and absorption.

Q. What EFFECT has the cultivation of the SOIL on the climate?

A. Wild and uncultivated land fills the air with noxious vapours; the draining of marshes and the felling of forests give free circulation to the atmosphere, and effect a wonderful change in the climate.

Q. Do the WINDS AFFECT the climate?

A. Yes; all other influences are modified by the prevalent winds.

Q. How is climate AFFECTED by the QUANTITY of RAIN which falls?

A. By the evaporation from the earth, and the moisture in the atmosphere.

CHAPTER XXIV.

WINDS.

Q. What is WIND?

A. *Air in motion.*

Q. What OCCASIONS those MOVEMENTS of the air which we call wind?

A. The principal cause is the *variation of temperature* produced by the alternation of day and night and the succession of the seasons.

Q. How can winds originate through VARIATIONS of TEMPERATURE?

A. When through the agency of the sun a particular portion of the earth's surface is heated to a greater degree than the remainder, the air resting upon it becomes *rarefied* and *ascends*, while a current of cold air rushes in to supply the vacancy. Two currents, the one of

warm air flowing out, and the other of cold air flowing in, are thus continually produced; and to these movements of the atmosphere we apply the designation of *wind*.

Q. Does the wind ALWAYS BLOW?

A. Yes; there is always *some motion* in the air; but the *violence* of the motion is perpetually varying.

Q. Does the ROTATION of the EARTH upon its axis effect the motion of the air?

A. Yes; in *two ways:* 1. As the earth moves round its axis, the thin movable air is left somewhat *behind*, and therefore seems (to a stationary object) to be blowing in the *opposite* direction to the earth's motion; and

2. As the earth revolves, *different portions* of its surface are continually passing under the *vertical rays of the sun.*

Q. What is meant by "VERTICAL RAYS?"

A. When the sun is in a *direct line* above any place, its rays are said to be "vertical" to that place.

Q. Why is not the WATER of the sea made so HOT by the vertical sun as the surface of the LAND?

A. Because the *evaporation* of the sea is greater than that of the land; the constant *motion* of the water prevents the increase of temperature at the surface; and water is a bad conductor of heat.

Q. Does the MOTION of the SEA prevent its surface from being HEATED by the direct rays of the sun?

A. Yes; the *rolling motion* of the water *prevents* the surface being *heated* to a greater degree than the water below it; the *evaporation* also *absorbs* the heat in the generation of vapour, and carries it off into the air.

Q. Why are those winds which blow over LARGE CONTINENTS or TRACTS of LAND generally DRY?

A. Because in their passage they *absorb very little water*, as they do not blow over large oceans.

Q. Why do our HANDS and LIPS CHAP in frosty and windy weather?

A. 1. Because the wind or frost absorbs the *moisture* from the surface of the skin; and

2. This action of wind or frost produces a kind of inflammation on the skin.

Q. Do CLOUDS affect the WIND?

A. Yes. As passing clouds screen the direct heat of the sun from the earth, they diminish the *rarefaction of the air also;* and this is *nother* cause why neither the strength nor direction of the wind is *uniform.*

Q. Would the wind blow REGULARLY from east to west if all OBSTRUCTIONS were REMOVED?

A. Without doubt. If the whole earth were covered with *water*, the winds would always *follow the sun*, and blow uniformly in *one direction.*

Q. Do winds EVER blow REGULARLY ?

A. Yes; in those parts of the world which present a *large surface of water*, as in the Atlantic and Pacific oceans.

Q. With what VELOCITY do winds move ?

A. *Every graduation* exists in the speed of winds, from the mildest zephyr to the most violent hurricane.

Q. With what velocity does a wind which is HARDLY PERCEPTIBLE move ?

A. With a velocity of about *one mile per hour.*

Q. In a gentle wind, what is the VELOCITY ?

A. From *four to five miles per hour.*

Q. In a pleasant BRISK GALE, what is the velocity ?

A. From *ten to fifteen miles per hour.*

Q. In a very BRISK WIND, what is the velocity ?

A. From *twenty to twenty-five miles per hour.*

Q. In a very HIGH WIND, what is the velocity ?

A. From *thirty to thirty-five miles per hour.*

Q. What is the velocity of the wind in a STORM ?

A. From *fifty to sixty miles per hour.*

Q. In a HURRICANE, what is the estimated velocity ?

A. From *eighty to one hundred miles per hour.*

Q. Why do we sometimes see CLOUDS at one elevation moving in ONE DIRECTION, and at ANOTHER ELEVATION, at the same time, others moving in a CONTRARY DIRECTION ?

A. Because *different currents of air* exist at *different elevations*, moving in different directions, with different velocities.

In 1839, an English aeronaut, at the height of 14,000 feet, encountered a current that bore him along at the rate of five miles per hour; but, upon descending to the altitude of 12,000 feet, he met with a contrary wind, blowing with a velocity of eighty miles per hour.

Q. How is the FORCE of the wind ascertained ?

A. By observing the *amount of pressure* that it exerts upon a given plane surface *perpendicular to its own direction.*

If the pressure plate acts freely upon spiral springs, the power of the wind is denoted by the extent of their compression, and that weight will be a measure of their force, the same as in weighing by the ordinary spring-balance.

Q. What is an INSTRUMENT for measuring the force of the wind CALLED ?

A. An *Anemometer.*

Q. Into what THREE CLASSES may winds be divided ?

A. Into *constant*, *periodical*, and *variable* winds.

SECTION I.—CONSTANT WINDS.

Q. What name is given to the constant winds which blow over the ATLANTIC and PACIFIC Oceans ?

A. That of "*trade winds.*"

Q. Why are they called "TRADE-WINDS ?"

A. Because they are very convenient to *navigators* who have to cross the ocean, as they always blow in *one direction.*

Q. In what DIRECTION do the TRADE-WINDS blow?

A. That in the northern hemisphere blows from the north-east; that in the southern hemisphere from the south-east.

Q. Why do they not blow from the DIRECT NORTH and SOUTH?

A. Because as the earth rolls every day once round itself from west to east, air that has acquired slow movement at the poles finds the globe travelling *too fast* for it at the equator, and is obliged therefore to drop more and more behind.

Q. What is the CAUSE of these currents of air from the POLES to the EQUATOR?

A. The heated air *expands near the equator*, rises and runs over towards either pole in two grand upper currents, under which there flow from north and south two deluges of colder air to occupy the space vacated, and to restore the equilibrium.

Q. Is there an UPPER as well as a LOWER CURRENT in the atmosphere?

A. Yes; the *upper* current is *from the equator to the poles*, where it is condensed, and thence returns as *the lower current* to the *equator*.

Q. These LOWER CURRENTS (from the poles to the equator) have an EASTERLY tendency: explain the cause of this.

A. All the atmosphere revolves *with the earth;* but when a current of air from the *poles* flows towards the *equator*, it comes to a part of the earth's surface which is moving *faster than itself;* in consequence of which it is *left behind*, and thus produces the effect of a current moving in the opposite direction.

Thus, to a person in a carriage, the hedges and trees seem to be running in an opposite direction.

As the circumference of the earth at the equator is much larger than the circumference of the earth at the poles, therefore every spot of the earth's equatorial surface must move much faster than the corresponding one at the poles.

As the earth revolves on its axis from west to east, therefore the air which is carried with it will seem to blow from the west. As, however, the current of air from the poles seems to blow in the opposite direction, it will seem to blow from the east, or to be an easterly wind.

Q. By what MEANS are the north-east and south-east TRADE-WINDS PRODUCED?

A. By a combination of the two motions of the *polar currents*, which produces the intermediate directions of the *north-east* and *south-east*.

Q. Are BOTH these MOTIONS of the polar currents REAL?

A. No; the motion from the east to west is only *apparent*. As the earth revolves from *west* to *east*, the air carried with it will be a *west* wind; but the polar currents seem to blow in the *opposite direction*, merely because they have not *acquired the same velocity*.

Q. Do trade-winds blow from the north-east and south-east ALL the YEAR ROUND?

A. Yes, *in the open sea;* that is in the Atlantic and Pacific Oceans, for about 25° each side of the equator.

Q. What do the north-easterly and south-easterly trade-winds PRODUCE when they MEET near the equator?

A. A region of *calms* and variable winds, in which thick foggy air prevails, with sudden showers and thunderstorms.

Q. Is this region of calms FIXED in its position?

A. No; it shifts its place according to the sun's distance and position in regard to the *equator*, being sometimes entirely to the *north* of the equator, and occasionally reaching as far as 2° *south* of it.

Q. In the INDIAN OCEAN do the trade-winds ALWAYS blow north-east and south-east?

A. No; from April to October a *south-east* wind prevails, and from October to April a *north-east* wind sets in.

Q. Why do not the trade-winds blow UNINTERRUPTEDLY from POLE to POLE?

A. The hot air that ascends from the equator and passes north, gradually cools, and becomes *denser and heavier*, running as it does over the cold current below. The cold air from the pole, too, gradually becomes *warmer* and *lighter* as it passes south, so that in the temperate climates there is a constant struggle as to which shall have the upper and which the lower position. In these regions, consequently, there are no uniform winds.

Q. Where do the trade-winds blow with UNIFORM FORCE and constancy?

A. In many parts of the Pacific embraced within the region of the trade-winds, a vessel may *sail for a week* without *altering the position of a sail or rope.*

Q. How does the MEETING of the opposing winds produce a region of CALMS and VARIABLE WINDS?

A. Because the forces of the opposing winds *counterbalance one another*, and the atmosphere becomes *motionless.* When their relative strength becomes changed, as it sometimes rapidly does, short and sudden gusts and squalls arise.

SECTION II.—PERIODICAL WINDS.

Q. What are MONSOONS?

A. Monsoons are *regular periodical winds* which sweep over the Indian Ocean and the whole of Hindostan, as the sun moves into the northern or southern hemispheres; they are on this account called *monsoons.*

Q. Why is the term "MONSOON" given to them?

A. The term is derived from a Persian word *monsum*, signifying "*season.*"

Q. What are the LIMITS of the MONSOONS?

A. The *south-west* monsoon reaches from the east coast of Africa to the coasts of China; the *north-east* monsoon prevails from May to October within the same limits; the *north-west* extends from Madagascar to New Holland; and the *south-east* in the same limit from April to October.

Q. What is the SHIFTING of these periodical winds called by sailors?

A. The *breaking up* of the monsoon.

Q. By what PHENOMENA are these changes accompanied?

A. Generally by *great and terrible storms.*

Q. Are the MONSOONS SERVICEABLE to sailors?

A. Yes; as it often happens that a ship is wafted by a monsoon to a distant port, and enabled by their shifting to return in an opposite direction.

Q. How is the CHANGE of the MONSOONS MARKED?

A. By an interval of alternating calms and storms.

Q. What is the CAUSE of a SEA BREEZE?

A. When the *land* is *more heated by the sun* than the *sea* is, the *land* air becomes hotter than that over the *sea;* in consequence of which the cooler sea air glides *inland* to restore the equilibrium.

Q. Why does a SEA BREEZE feel COOL?

A. Because the sun cannot make the surface of the *sea* so hot as the *land;* therefore the air which blows from the sea is *cooler than the air of the land.*

Q. Is there a FRESH SEA BREEZE during the summer and autumn MORNINGS?

A. Yes; as the *land* air is *more heated by the sun* than that of the *sea*, the cool sea breeze glides *inland* to restore the equilibrium.

Q. Are TROPICAL ISLANDS subject to a LAND BREEZE every evening?

A. Yes; as the *surface of the land*, after sunset, cools down *faster* than the surface of the *sea*, the cold *air* of the land is *condensed*, *sinks down*, and spreads itself into the *sea air*, causing the *land breeze.*

SECTION III.—VARIABLE WINDS.

Q. In what REGIONS do variable winds prevail?

A. In what are called the *extra-tropical* regions.

Q. WHY do variable winds prevail mostly in the extra-tropical regions?

A. In the tropics, the great aerial currents known as the trade-winds exist in *all their power*, and control most of the local influences; but in the temperate zones, where the force of the trade-winds is diminished, a *perpetual contest* occurs between the permanent and temporary currents, giving rise to constant *fluctuations* in the *strength* and *direction* of the winds.

Q. Why are EAST WINDS generally DRY?

A. Because they come over *large tracts of land*, absorb *very little water*, and being thirsty, therefore *bring dry weather.*

Q. Why are NORTH WINDS generally COLD and DRY?

A. Because they come from *colder* regions, and being *warmed* by the heat of our climate, *absorb moisture* from everything they touch; in consequence of which they are generally dry.

Q. Why are SOUTH WINDS generally WARM?

A. Because they come over countries warmer than our own, where they are much heated.

Q. Why are WINDS which blow over a vast BODY of WATER generally RAINY?

A. Because they come laden with *vapour;* if, therefore, they meet with the least *chill*, some of the vapour is deposited as rain.

Q. Why do SOUTH WINDS often bring RAIN?

A. Because, coming from the torrid zone, they are much *heated*, and *imbibe water very plentifully* as they pass over the ocean.

Q. How does this account for the RAINY character of SOUTH winds?

A. As soon as they reach a cold climate they are *condensed*, and can no longer hold all their vapour in suspension; in consequence of which some of it is deposited as rain.

Q. Why are DRY WINDS in the spring months desirable and advantageous for agricultural operations?

A. They *dry the soil* saturated with moisture of winter, *break up the heavy clods*, and fit the land for the *seed* committed to it.

Q. What are the so-called "PUNA" winds of South America?

A. They are winds coming from the *snowy peaks of the Andes* which sweep over the high table-lands of South America.

They are so extremely dry and cold, that they absorb the moisture of dead animal bodies with such rapidity as to prevent putridity. If a mule happens to die upon one of these plains, it is converted in the course of a few days into a mummy, even the entrails being free from the slightest evidence of decay.

Q. What is the "SIMOOM?"

A. It is an *intensely hot wind* that prevails upon the *vast deserts of Africa* and the *arid plains of Asia*, causing great suffering, and often destruction of whole caravans of men and animals.

Q. How does the simoom ORIGINATE?

A. Its origin is to be sought in the *peculiarities of the soil*, and the *geographical position* of the countries where it occurs.

The surface of the deserts of Africa and Asia is composed of dry sand, which the rays of the sun render burning to the touch. The heat of these regions is insupportable, and their atmosphere like the breath of a furnace. When, under such circumstances, the wind rises and sweeps over these plains, it is intensely hot and destitute of moisture, and at the same time bears aloft with it great clouds of fine sand and dust—a dreadful visitant to the traveller of the desert!

Q. What is a HURRICANE?

A. The hurricane is a *remarkable storm wind*, peculiar to certain portions of the world. It rarely takes its rise beyond the tropics, and it is the only storm to be dreaded within the region of the trade-winds.

Q. How are hurricanes especially DISTINGUISHED from other kinds of tempests?

A. By their *extent*, *irresistible power*, and the *sudden changes* that occur in the *direction* of the wind.

Q. Do any PARTICULAR PORTIONS of the TROPICS appear to be especially visited with hurricanes?

A. In the northern hemisphere, hurricanes most frequently occur in the regions of the *West Indies;* in the southern hemisphere, they occur at the *Mauritius.*

Q. Do the hurricanes occur at PARTICULAR SEASONS?

A. The West Indian occur from *August to October;* the Mauritian from *February to April.*

Q. What have RECENT INVESTIGATIONS shown the hurricanes to be?

A. *Extensive storms of wind*, which *revolve round an axis*, either

upright or inclined to the horizon; while at the same time the body of the storm has a *progressive motion* over the surface of the ocean.

Q. ILLUSTRATE more clearly the MANNER in which a hurricane MOVES?

A. It is the nature of a hurricane to travel *round and round*, as well as *forward*, very much as a corkscrew travels through a cork, only the circles are all *flat*, and described by a rotatory wind upon the surface of the water.

Q. What EFFECT has this rotatory movement of the wind upon the water of the ocean and the surrounding atmosphere?

A. The rotatory wind blows the sea with it in a *rotatory current;* within the circle of the hurricane the air is *calm*, and its diminished pressure lifts the water up in a great storm-wave, which, advancing with the hurricane surrounded by its current, becomes a deluge if it strike upon a shore; but otherwise rolls on and on, while the wind dances round and round it, thus twisting circles while it marches on its main path—that main path being itself a grand curve.

Q. In what DIRECTIONS do the northern and southern hurricanes move?

A. Hurricanes always travel *away from the equator.* North of the equator, the great storm, revolving as it comes, generally rolls from the south-east to the north-west, until it has passed the northern tropic, when its course changes from south-west to north-east; the rotation of the storm being from right to left, contrary to the motion of the sun.

It always comes in that way; always describes in its main course the curve of an ellipse, which generally crosses the West India Islands, and presently, pursuing the ellipse, marches to the north-east from the coast of Florida, treading the waves of the Atlantic. In the southern hemisphere, hurricanes come from the north-east, and pursue a course away from the equator precisely similar.

Q. In what MANNER can you sketch upon a MAP the course of a West India hurricane?

A. Take an egg, and place it on an atlas map so that its small end shall be near the coast of Florida, and its lower edge rest on the Leeward Islands; take a pencil, and beginning eastward of these islands, trace the outline of your egg towards the west, turning its corner, and still tracing on towards north-east, as if travelling to Europe; leave off now, and you have sketched the ordinary elliptical path of a West Indian hurricane.

Q. In what DIRECTION would a ship revolving in the circles of a hurricane find the wind?

A. As the ship revolved, she would in turn find the wind blowing from *every point of the compass.*

Q. What is known concerning the DISTANCE travelled by HURRICANES?

A. The distance traversed by these terrible tempests is immense. The great gale of August, 1830, which occurred at St. Thomas on the 12th, reached the Banks of Northumberland on the 19th, having travelled more than *three thousand nautical miles* in *seven days;* the track of the Cuba hurricane of 1844 was but little inferior in length.

Q. What is known of their PROGRESSIVE and ROTARY VELOCITY?

A. Their progressive velocity is from *seventeen to forty miles per*

hour; but distinct from the *progressive* velocity is the rotary, which increases from the exterior boundary to the centre of the storm, near which point the force of the tempest is greatest, the wind sometimes blowing at the rate of *one hundred miles per hour.*

Q. How great is the BREADTH of the hurricane?

A. The surface simultaneously swept by these tremendous whirlwinds is a vast circle varying from *one hundred to five hundred miles* in diameter.

Q. How great is the SURFACE over which they PREVAIL?

A. The great Cuba hurricane of 1844 was estimated to have been not less than *eight hundred miles* in breadth, and the area over which it prevailed during its whole length was computed to be *two million four hundred thousand square miles*—an extent of surface equal to two-thirds of that of all Europe.

Q. What CURIOUS FACT have mariners noticed when in the centre or vortex of the hurricane?

A. An awful *calm* evails, described as the *lull* of the tempest, in which it seems to have rested only to gather strength for greater efforts.

Q. In a hurricane, how does the BAROMETER RISE and FALL?

A. During the *first half* of the storm the barometer *falls*, and during the *last half* it *rises.*

Q. WHY does the barometer rise and fall in this manner?

A. Because the *density* of the air *increases* from the *centre to the circumference* of the storm, and even beyond its boundary; so that when a hurricane passed diametrically over a district, the atmospheric pressure would decrease, and the barometer continue to sink during the first half of the storm, but gradually rise as the last half passed over.

Q. What is the CONDITION of the ATMOSPHERE included within the circle of the hurricane?

A. The hurricane being a vast whirlwind, the atmosphere constituting the body of the storm will be *driven outwards* from the centre towards the margin, just as water in a pail which is made to revolve rapidly, flies from the centre and swells up at the sides. But the pressure of the atmosphere beyond the whirl, checking and resisting the centrifugal force, at length arrests the outward progress of the mass of air, and limits the storm.

Q. In tropical climates, what INDICATIONS does the barometer afford of the approach of a hurricane?

A. The mercury in the tube is *depressed* or agitated in an extraordinary manner, for some time before any indications of a storm appear in the horizon.

Q. What very CURIOUS INSTANCE may be mentioned of the sailing of a ship caught in a hurricane?

A. In 1845, a ship encountered a hurricane near Mauritius. The wind, as the ship sailed in the circuit of the storm, changed *five*

times completely round in one hundred and seventeen hours. The whole distance sailed by the vessel was thirteen hundred and seventy-three miles, and at the termination of the storm she was only three hundred and fifty-four miles from the place where the storm commenced.

Q. WHO discovered and demonstrated this theory of the hurricane?

A. The credit of making known these important facts belongs principally to *Colonel Reid*, of England, and *Mr. William C. Redfield*, of New York.

Q. How has a knowledge of the laws governing the movements of the hurricane been of PRACTICAL VALUE to the interests of navigation?

A. *Rules* have been published by which a sailor may know the *exact course* of the hurricane he may happen to encounter, which enable him to steer his ship so as she can ride safely until the hurricane is gone.

Without such knowledge, puzzled by the changing wind, he perhaps drives before it, and is whirled round, circle after circle, dragged through the very road of danger; or he escapes into the middle of a circle, has a little breathing time, and presently the crash returns; or he gets out of the main course, and through ignorance encounters it again. Shipwrecks innumerable have been caused in this way. In the present day, though we have not yet established a full theory concerning hurricanes, the sailor has been taught to step out of their path.

Q. What are the ACCOMPANIMENTS of a hurricane?

A. *Thunder and lightning*, and *torrents of rain.*

Q. What is the TYPHOON?

A. The typhoon is a *storm of wind* somewhat resembling the hurricane. It is met with only in the *China seas*, not so far south as the island of Mindanao, nor so far north as Corea, except upon the eastern borders of Japan.

Q. In what RESPECT does a TORNADO differ from a HURRICANE?

A. Tornadoes may be regarded as hurricanes, differing chiefly in respect to their *continuance* and *extent.*

Q. How LONG do they usually LAST?

A. From *fifteen to seventy seconds.*

Q. What is their EXTENT?

A. Their breadth varies from a *few rods to several hundred yards*, and the length of their course rarely exceeds *twenty miles.*

Q. What PHENOMENA generally attend them?

A. The tornado is generally *preceded by a calm and sultry state of the atmosphere*, when suddenly the whirlwind appears, *prostrating everything* before it. Tornadoes are usually accompanied with thunder and lightning, and sometimes showers of hail.

Q. What CURIOUS EFFECT does a tornado sometimes have upon fowls and birds overtaken by it?

A. They are often entirely *stripped of their feathers.*

Q. What CURIOUS THEORY was propounded some years since to account for this phenomenon?

A. The author of the theory supposed that in the vortex or centre

of the tornado there was a *vacuum*, and the fowls being suddenly caught in it, the air contained in the barrel of their quills expanded with such force as to strip them from the body.

Q. What is supposed to be the ORIGIN of tornadoes?

A. They are supposed to be generally produced by the *lateral action* of an *opposing* wind, or the influence of a brisk gale upon a portion of the atmosphere in repose.

Q. How are the EDDIES, or WHIRLPOOLS, produced which occur in water, and which, in their formation, resemble some tornadoes?

A. Eddies, or whirlpools, are most frequently formed in water when *two streams* flowing unequally meet. They may be seen at the junction of two brooks or rivers.

Q. How are the whirlwinds which we frequently see at the CORNERS of STREETS in cities produced?

A. They are caused by a *gust of wind* sweeping round a corner of a building, and striking the calm air beyond it.

Q. Where does the WHIRL of the whirlwind appear to ORIGINATE?

A. In the *higher regions of the atmosphere;* it increases in velocity as it descends, its base gradually approaching the earth, until it rests upon the surface.

Q. What is the EFFECT of EXTENSIVE FIRES in producing whirlwinds?

A. Great conflagrations sometimes produce whirlwinds, in consequence of a strong upward current, which is produced by the expansion of the heated air.

Q. What REMARKABLE EXAMPLE of this phenomenon is on record?

A. At the *burning of Moscow*, 1812, the air became so rarefied by heat, that the wind rose to a frightful hurricane.

Q. What is a WATERSPOUT?

A. A waterspout is a *whirlwind over the surface of water*, and differs from a whirlwind on land in the fact that water is subjected to the action of the wind, instead of objects on the surface of the earth.

Q. When an observer is near, are any SOUNDS perceptible?

A. A *loud hissing noise* is heard, and the interior of the column seems to be traversed by a rushing stream.

Q. What is the BREADTH and HEIGHT of waterspouts?

A. In diameter the spout at the base ranges from a *few feet* to *several hundreds*, and its altitude is supposed to be often *upwards of a mile.*

Q. What are its SUCCESSIVE APPEARANCES?

A. At first it appears to be a *dark cone*, extending from the clouds to the water; then it becomes a *column* uniting with the water. After continuing for a little time, the column becomes disunited, the cone re-appears, and is gradually drawn up into the clouds.

Q. Is it supposed that water is SUCKED UP from the ocean or lake by the water-spout?

A. It is a *common belief* that water is sucked up by the action of

the spout into the clouds; but there is reason to suppose that water rather *descends* from the clouds, as water which has fallen from a spout upon the deck of a vessel has been found to be fresh. There is no evidence, furthermore, that a continuous column of water exists within the whirling pillar.

Q. What are SAND-PILLARS?

A. They are *gigantic columns of sand* raised by whirlwinds in the deserts of Africa and other countries. They sometimes extend as *high* as the *clouds*, and move with various degrees of velocity, carrying destruction in their paths.

Q. Why does WIND generally feel COLD?

A. Because a *constantly-changing surface* comes in contact with our body to draw off its heat.

Q. What are the EFFECTS of wind noticed in the Arctic regions?

A. Sir John Richardson, Dr. Kane, and other Arctic explorers inform us that in those regions when the thermometer ranges from 40° to 60° below zero, the cold of the external air is *easily endurable*, provided the air is *calm*, and the *individual exercises freely;* but if a wind arises at this temperature, the *severity* of the cold becomes *too great* for *human endurance.*

Q. If the winds should cease to blow over the ocean, what would be the EFFECT?

A. The water would undoubtedly *become stagnant.* Tempests and hurricanes also exercise a beneficial effect by agitating and purifying the atmosphere, and sweeping from it the seeds of pestilence and contagion.

CHAPTER XXV.

CLOUDS.

Q. What are CLOUDS?

A. Masses of condensed vapour floating in the air.

Q. From WHENCE are they derived?

A. They are evaporated, or drawn up from the earth.

Q. Are CLOUDS and FOGS the SAME in their character?

A. They are caused in the same way, but while fogs cling to the earth, clouds rise above it.

Q. Why are CLOUDS HIGHER ON A FINE DAY?

A. Because they are *lighter* and *more buoyant.*

Q. Why are CLOUDS LIGHTER ON A FINE DAY?

A. 1. Because the vapour of the clouds is *less condensed;* and

2. The *air itself* (on a fine day) retains much of its vapour in an *invisible* form.

Q. How do you ACCOUNT for CLOUDS FLOATING in the AIR?

A. By their lightness and the buoyancy of their composition.

Q. Of WHAT are they COMPOSED?

A. The vapour of which they consist is formed into small globules or bubbles, which give lightness and buoyancy to the cloud.

Q. What are these GLOBULES called?

A. Vesicles.

Q. What CIRCUMSTANCES occasion VARIETY in the appearance of the CLOUDS?

A. Their colour, their weight, and their height above the earth.

Q. What is the CHIEF CAUSE of fog and clouds?

A. During the daily process of evaporation from the surface of the earth, warm, *humid currents* of air, are continually *ascending;* the higher they ascend, the colder is the atmosphere into which they enter; and as they continue to rise, a point will at length be attained where, in union with the colder air, their original humidity can no longer be retained: a cloud will then appear, which increases in bulk with the upward progress of the current into colder regions.

Q. Are ALL countries alike subject to a CLOUDY atmosphere?

A. No; very great differences exist.

Q. On WHAT do these DIFFERENCES chiefly depend?

A. On variable winds; thus the variable winds which prevail in England cause our atmosphere to be very cloudy. In Egypt, where the temperature is higher and more equal, the sky is seldom clouded.

Q. Do changes in the WIND produce CLOUDS?

A. Yes; a warm current of air disperses the clouds by absorbing the vapour of which they are composed; but a cold current of air, on the contrary, condenses the vapour in the air, and produces cloud and rain.

Q. What DISTANCE are the CLOUDS from the EARTH?

A. Some *thin, light clouds* are elevated above the highest mountain-top; some *heavy* ones touch the steeples, trees, and even the earth; but the *average* height is between *one and two miles.*

Streaky, curling clouds, like hair, are often five or six miles high.

Q. Does the HEIGHT of the CLOUDS VARY with the SEASON of the year?

A. Yes; their height is much greater above the earth in summer than in winter.

Q. What is the ORDINARY size of CLOUDS?

A. The size of clouds is very variable; while some only measure a few square yards, others extend over many miles.

Q. Is it POSSIBLE to ascertain the THICKNESS of a CLOUD?

A. Yes; this is often quite easy, as the tops of some lofty mountains rise higher than the clouds, so that travellers pass through them before they arrive at the summit. Balloons also pass through and rise above the clouds.

Q. Is there any VARIETY in the SHAPE of the CLOUDS?

A. An almost endless variety of shape is assumed by the clouds in the atmosphere.

Q. Is there any CLASSIFICATION of these varied forms adopted by scientific men?

A. Yes; they have been arranged in a classified order, which is now generally admitted.

Q. How is this VARIETY in the shape of the CLOUDS OCCASIONED?

A. By their origin, their electrical state, and the prevailing currents of air.

Q. Does, then, ELECTRICITY affect the SHAPE of CLOUDS?

A. It does; and, if one cloud be *full of electricity* and another *not*, they will be *attracted* to each other, and either mingle or disappear altogether.

Q. Why do clouds, when not continuous over the whole surface of the sky, appear JAGGED, ROUGH, and UNEVEN?

A. The *rays of the sun*, falling upon different surfaces at different angles, *melt away* one set of elevations, and *create* another set of depressions; the heat also which is liberated from below in the process of condensation, the currents of warm air escaping from the earth, and of cold air descending from above, all tend to keep the clouds in a state of agitation, upheaval, and depression. Under their various influences, the masses of vapour composing the clouds are caused to assume all manner of grotesque and fanciful shapes.

Q. What EFFECT have WINDS on the SHAPE of CLOUDS?

A. They sometimes *absorb them entirely;* sometimes *increase their size and weight;* and sometimes *change the position of their parts.*

Q. Has not the WIND at some periods an entirely OPPOSITE EFFECT ON CLOUDS from that which it has at another?

A. This depends on whether the wind or current of air be hot or cold. If it be a warm, dry wind, it disperses or converts the cloud into invisible vapour; if it be a cold wind, it increases the bulk and density of the clouds.

Q. Why are MORNING CLOUDS generally of a RED tinge?

A. Because red rays are the *least refrangible* of all; and not being *bent* so much as blue and yellow rays, we see them sooner in the morning.

Q. Why is not the COLOUR of CLOUDS always ALIKE?

A. Because their *size*, *density*, and *situation* in regard to the sun are perpetually varying, so that sometimes *one* colour is reflected and sometimes *another.*

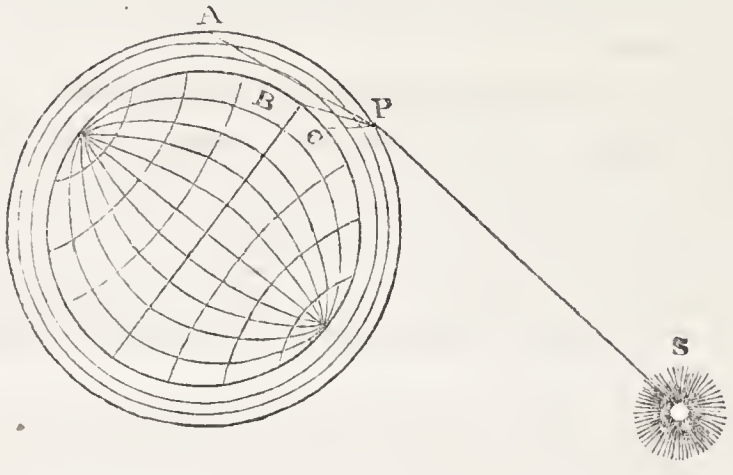
Q. Why are the LAST CLOUDS of EVENING generally of a RED tinge?

A. Because *red* rays (being the *least refrangible* of all) are the *last to disappear.*

Let us suppose, as in fig. 83, a ray of light proceeding from the sun S to enter the earth's atmosphere at the point P. The red rays, which compose in part the solar beam,

being the least refrangible, or the least deviated from their course, will reach the eye of a spectator at the point A; while the yellow and blue rays, being refracted to a greater degree, will reach the surface of the earth at the intermediate points B and C. They will, consequently, be quite invisible from the point A.

Fig. 83.



Q. What is meant by being "LESS REFRANGIBLE?"

A. Being *less able to be bent.* Blue and yellow rays are more easily bent *below the horizon* through the action of the atmosphere, but red rays are not so much *bent down*, and therefore we see them later in the evening, as at A, in *fig.* 83.

Q. What REGULATES the MOTION of the CLOUDS?

A. Principally the *winds;* but sometimes *electricity* will influence their motion also.

Q. How do you know that CLOUDS MOVE by OTHER INFLUENCES besides WIND?

A. Because (in calm weather) we often see *small clouds meeting each other* from opposite directions.

Q. How do you know that ELECTRICITY affects the MOTION of the clouds?

A. Because clouds often meet from *opposite directions*, and having discharged their opposite electricities into each other, *vanish altogether.*

Q. What are the USES of CLOUDS?

A. They act as *screens* to protect the earth from the heat of the *sun's rays;* they are the great *storehouses of rain*, and carry the *electric fluid.*

Q. What is the CAUSE of a RED SUNSET?

A. The vapour of the air not being *actually condensed into clouds*, but only on the *point of being condensed.*

In the same manner, if light be transmitted through steam mingled with air, and therefore on the verge of condensation, it assumes a deep orange or red colour.

Q. Why is a RED SUNSET an indication of a FINE DAY to-morrow?

A. Because although *watery vapour* is present in the air, it is probably only on the verge of *incipient condensation*, and not sufficiently condensed to form rain clouds; and this slowly progressive transition of vast volumes of the air through the temperature of the

dew point can only occur in serene weather at sunset, and not at sunrise.

Q. What is the CAUSE of a COPPERY, YELLOW SUNSET?

A. The *vapour* of the *air* in the process of being *condensed into clouds.*

Q. Why do CONDENSED VAPOURS reflect YELLOW RAYS?

A. Because the beams of light are refracted, or turned from their path, in a great degree by condensed vapour, in consequence of which those rays are bent down to the eye which are more refracted than the red, such as yellow.

Q. What is the CAUSE of a RED SUNRISE?

A. Vapour in the upper region of the air *just on the point of being condensed.*

Q. Why is a RED and LOWERING sky at SUNRISE an indication of a WET DAY?

A. The red and lowering appearance of the morning sky, which indicates foul weather, probably depends upon such an *excess of vapour* being present in the whole atmosphere that clouds are actually *forming in the higher regions*, or upon the point of condensation, which the rising sun cannot disperse.

Hence our Lord's observation: "In the morning ye say, It will be foul weather to-day, for the sky is red and lowering." (Matt. xvi. 3.)

Q. Why is a GRAY MORNING an indication of a FINE DAY?

A. Because only the air *contiguous to the earth* is damp and full of vapour. There are no vapours in the *higher* regions of the air to bend down to the eye even the red rays of any beam of light.

Q. What DIFFERENCE (in the state of the air) is required to make a GRAY and RED SUNRISE?

A. In a *gray* sunrise, only that portion of air *contiguous to the earth is filled with vapour;* all the rest is clear and dry. But in a *red* sunrise, the air in the *upper regions* is so full of vapour that the rising sun cannot disperse it.

Q. Why is a GRAY SUNSET an indication of WET weather?

A. Because it shows that the air on the *surface of the earth* is very *damp* at *sunset*, which is a plain proof that the air is *saturated with vapour*, the vapour having accumulated during the day in opposition to the sun's influence; in consequence of which wet may be soon expected: hence the rhyme:—

"Evening red and morning gray
Will set the traveller on his way;
But evening gray and morning red,
Will bring down rain upon his head."

Q. Which is the most TRANSPARENT, dry or moist air?

A. Air *moderately moist* is more transparent than very dry air.

Q. What is the CAUSE of the HAZINESS of the atmosphere during that portion of the autumn in America known as the "Indian Summer?"

A. It is undoubtedly due to several causes; partially to an *exces-*

sive dryness of the atmosphere, and, in some degree, to the *prevalence of smoke* in the air, arising from burning forests. But it is also a fact, ascertained within a few years, that the constitution of the atmosphere is changed in the autumn, and that solar light at that season has less chemical influence than at any other portion of the year.

Q. Why does the SUN seen through a fog appear RED?

A. Because the red rays of light have a *greater power* to pass through a *thick, dense atmosphere*, than any of the other coloured rays.

Q. Why does VAPOUR sometimes form into CLOUDS, and sometimes rest upon the earth as MIST or FOG?

A. This depends on the *temperature* of the air. When the *surface* of the earth is *warmer* than the *lower air*, the vapour of the earth (being condensed by the chill air) becomes *mist* or *fog*. But when the *lower air* is *warmer* than the earth, the vapour *rises through the air*, and becomes cloud.

Q. Why do clouds often hover around MOUNTAIN PEAKS, when the atmosphere elsewhere is clear and free from clouds?

A. It is caused by the wind impelling up the sides of the mountains the *warm humid air of the valleys*, which in its ascent gradually becomes condensed by the cold, and its excess of moisture becomes visible, and appears as a cloud.

SECTION I.—MODIFICATIONS OF CLOUDS.

Q. Into how MANY CLASSES are the different sorts of CLOUDS divided?

A. Into *seven* kinds; three original—viz., the *cirrus*, the *cumulus*, the *stratus*; and four formed by combination—viz., the *cirro-cumulus*, the *cirro-stratus*, the *cumulo-stratus*, and the *nimbus*.

Q. What are CIRRUS CLOUDS?

A. They are distinguishable from other clouds by the lightness of their appearance, and the variety of forms they are capable of assuming.

The clouds of the cirrus are formed of the purest aqueous vapour, symmetrical in arrangement, delicate but decisive in their sharpness of edge, infinitely multitudinous in their component parts, and of a vivid and unsullied white.

Q. What is their USUAL FORM?

A. After a period of fine weather, the *cirrus* clouds are seen stretching in white lines across the sky; at other times they resemble loose air; at others, a delicate, gauzy net-work.

Q. Why are these clouds called CIRRUS?

A. From the Latin word *cirrus*, a curl or lock of hair, on account of their appearance.

Q. Is the CIRRUS an ELEVATED cloud?

A. Yes; it rises to a great height: higher, in fact than any other

cloud. Its height at Halle, in Germany, was estimated at 21,300 feet.

Q. Of WHAT is it COMPOSED ?

A. The philosopher Kaemetz declares it to be composed entirely of snow flakes, as the temperature in which it floats must be far below freezing point.

Q. What are CUMULUS CLOUDS ?

A. They are huge masses of vapour, which appear to be heaped or piled together, and look like mountains in the sky.

Q. Why are they called CUMULUS ?

A. They derive their name from the Latin *cumulus*, a mass or pile.

Q. At what PART of the DAY do these CUMULUS CLOUDS mostly prevail ?

A. They prevail mostly in the morning, two or three hours before noon, and continue to the hottest part of the day, when they gradually disperse.

Q. How are they FORMED ?

A. By the ascending currents of warm air caused by the rays of the sun.

Q. Why do the cumulus clouds DISAPPEAR towards evening, and occur in the greatest number about noon ?

A. At *noon* the currents of warm air are more buoyant, larger, and rise higher, and being condensed, form large masses of clouds; but when in the afternoon the solar heat diminishes, the strength of the currents abates, the clouds which are buoyed up by their force sink down into warmer regions of the atmosphere, and are either partially or wholly dissolved.

Q. How is the ROUNDED FIGURE of the cumulus produced ?

A. The rounded figure of the cumulus has been attributed to its *method of formation;* for when one fluid flows through another at rest, the outline of the figure assumed by the first will be composed of curved lines.

Q. How may the cumulus be IMITATED and ILLUSTRATED ?

A. By suffering a *drop of milk* or *ink* to fall into a *glass of water*, the form of the cumulus can be imitated. The same thing is seen in the shape of a *cloud of steam* as it issues from the boiler of a locomotive.

Q. What SORT of clouds are those called STRATUS ?

A. *Stratus clouds*, or, as they are sometimes called, *full clouds*, are *creeping mists*, which rise from low, damp places, and are always *nearer* to the earth than other clouds.

Q. How is the name DERIVED ?

A. From the Latin *stratus*—that which covers or lays low.

Q. WHAT produces stratus clouds?

A. Beds of visible moisture, formed by some chilling effects acting along the *direct surface of the earth.*

Q. What is a frequent VARIETY of the stratus clouds?

A. Those *light* and *spreading mists* which gather in meadows and vales in the evening of a warm summer's day, and which float like a veil a short distance above the surface of the ground.

Fig. 84.

Cirrus, *a*; cumulus, *b*; and stratus, *c*.

Q. What are CIRRO-CUMULUS clouds?

A. *Cirro-cumulus* clouds are cirrus clouds springing from a massy centre, or heavy masses edged with long streaks, generally called "*mares' tails.*"

A system of small round clouds may be called cirro-cumulus.

Q. What are CIRRO-STRATUS clouds?

A. The *cirro-stratus*, or *wave-clouds*, are so called because they resemble both the *cirrus* and *stratus;* they form what is generally called a "*mackerel sky.*"

Q. What produces CIRRO-STRATUS clouds?

A. *Cirrus* clouds accumulating into *denser* masses, produce the intermediate class, called *cirro-stratus.*

Fig. 85 illustrates the appearance of the cirro-stratus, the cirro-cumulus, the nimbus, and the cumulo-stratus.

Fig. 85.

Cirro-stratus, *b, c, d;* cirro-cumulus, *a;* nimbus, *e;* cumulo-stratus, *f.*

Q. What is meant by CUMULO-STRATUS clouds

A. Those clouds which assume all sorts of *gigantic forms*, such as vast towers and rocks, scenes of battle, and cloudy giants. This class of clouds is the most romantic and strange of all.

Q. When is this FORM of cloud seen in PERFECTION?

A. Upon the *approach of a thunderstorm*, when the cumulus clouds, driven by the wind, are piled upon each other, and assume those peculiar forms known as "*thunder clouds.*"

Q. What are NIMBUS clouds?

A. All clouds from which *rain falls.* Nimbus is the Latin word for "*clouds which bring a storm.*"

Q. By what PARTICULAR CHARACTER may the nimbus (or rain cloud) be at once DISTINGUISHED?

A. By the want of a *defined outline;* its edge is gradually shaded off from the *deep gray mass* into *transparency.*

Q. What APPEARANCE takes place in the clouds at the approach of RAIN?

A. The *cumulus* cloud becomes *stationary*, and *cirrus streaks*

settle upon it, forming cumulo-stratus clouds; *black* at first, but afterwards of a *gray* colour.

Q. Why does a HAZE round the SUN indicate RAIN?

A. Because the *haze* is caused by *very fine rain falling in the upper regions of the air;* when this is the case, *a rain* of five or six *hours' duration* may be expected.

SECTION II.—MIST AND FOG.

Q. How are clouds, mists, and fogs PRODUCED?

A. By *evaporation.*

Q. Does moisture EVAPORATE at ALL temperatures?

A. Yes; even *ice* gives forth vapour.

Q. How is evaporation PRODUCED?

A. By the *solar heat.*

Q. What is the RESULT?

A. The *moisture* from the land or sea being *drawn up into the air*, there *condenses*, and assumes the form of mist, fog, or cloud.

Q. Does it RETURN to the EARTH?

A. Yes; in the *form* of rain, snow, or hail.

Q. Is the AIR ALWAYS capable of receiving VAPOUR from the EARTH?

A. A *certain quantity* of *air* can only receive a *certain quantity* of *vapour*, after which it is said to be *saturated*, and can take up no more.

Q. How do you ACCOUNT for the MIST which often covers WINDOWS at night?

A. The cold night air *chills* the window glass, *condensing* into mist the warm vapour of the room.

Q. How did this WARM VAPOUR arise?

A. The *air* of the room itself *contains vapour;* this vapour is *increased* by persons in the room and other incidental causes, such as the steam from hot victuals, or tea.

Q. Is not the GLASS of the WINDOW as HOT as the ROOM itself?

A. No; the *glass cools down rapidly after sunset*, while the *room* keeps at a *warmer* temperature.

Q. How does the PRESENCE of PEOPLE in the room INCREASE its vapour?

A. Their *breath* and *insensible perspiration add* to the *vapour* of the room.

Q. What is INSENSIBLE PERSPIRATION?

A. Perspiration which is *given forth constantly* by the *human body*, but which is not *perceptible*, as is the case with violent perspiration.

Q. By what SIMPLE EXPERIMENT can this be ascertained?

A. By putting the *naked arm* into a *clean, dry glass tube*, when the *perspiration* will *settle* as a *mist* upon the glass.

Q. Does not BREATHING on a GLASS produce the SAME EFFECT?

A. Yes; if we *breathe* on a piece of *glass* our breath is *condensed*, and forms a *mist* on its surface.

Q. Is our breath VISIBLE?

A. Only when it is *condensed into vapour.*

Q. WHEN does this occur?

A. When the weather is *intensely cold;* then our breath is *seen* as a *vapour*, resembling the appearance assumed by *steam.*

Q. What are FOGS?

A. Fogs are *visible vapours* that float in the atmosphere near the surface of the earth.

Q. What is the CAUSE of fogs?

A. They originate in the *same causes as rain*—the union of a cool body of air with one that is warm and humid; when the precipitation of moisture is slight, fogs are produced; when it is copious, rains are the result.

Q. What DISTINCTION is to be made between a mist and a fog?

A. *Mist* is generally considered to be a *fine rain*, while *fog* is *vapour*, not sufficiently condensed to allow of its precipitation in drops.

The term mist is also generally applied to *vapours* condensed on *marshes*, *rivers*, and *lakes*, while the name fog is often applied to *vapours* condensed on *land*, especially if those vapours are laden with smoke.

Q. Why does not the FOG become dew?

A. Because the chill of the air is so *rapid* that vapour is condensed *faster* than it can be *deposited*, and (covering the earth in a fog) prevents any further *radiation of heat* from the earth.

Q. When the earth can no longer RADIATE heat upwards, does it continue to CONDENSE the vapour of the air?

A. No; the air (in contact with the earth) becomes about equal in *temperature* with the surface of the earth itself; for which reason the fog is not *condensed* into *dew*, but remains *floating* above the *earth* as a thick cloud.

Q. This FOG seems to RISE HIGHER and HIGHER, and yet remains quite as DENSE below as at first: explain the cause of this.

A. The air resting on the *earth* is first chilled, and *chills* the air resting on *it;* the air which touches this *new layer* of fog being *also* condensed, layer is added to layer, and thus the fog seems to be *rising*, when (in fact) it is only *deepening.*

Q. WHEN is it that FOGS are MORE FREQUENT at NIGHT than in the DAY?

A. This occurs when the *vapour* taken up into the air has *saturated* the atmosphere, so that, as soon as the cold of night lessens its capacity for holding vapour, it *returns* the moisture to the earth in the shape of *mist* or *fog.*

Q. Where do FOGS mostly prevail?

A. In *lowland*, *marshy places*, and by *river sides.*

Q. WHY is this?

A. Such places *more readily give off vapour* and *saturate* the air, which, at the *least depression* of *temperature*, returns the moisture as mist or fog.

Q. In London, fogs have an EXTRAORDINARY DENSITY and DARK COLOUR: how is this to be ACCOUNTED FOR?

A. It is owing to the *smoke* which *mixes* with the *vapour*, and gives to it the *dark colour* named.

Q. Why does VAPOUR sometimes form into CLOUDS, and sometimes rest upon the earth as MIST or FOG?

A. This depends on the *temperature* of the air. When the *surface of the earth is warmer than the air*, the vapour of the earth (being condensed by the chill air) becomes *mist* or *fog*. But, when the *air is warmer than the earth*, the vapour *rises through the air*, and becomes cloud.

Q. Why do HILLS, &c., appear LARGER in WET weather?

A. Because the air is *laden with vapour*, which causes the rays of light to *diverge more;* in consequence of which they produce on the eye *larger images of objects.*

Q. Why do TREES, &c., in WET weather appear FARTHER OFF than they really are?

A. Because the fog or mist *diminishes the light* reflected from the object; and as the object becomes *more dim*, it seems to be *farther off.*

Q. Are fogs common on a FROSTY MORNING?

A. No; on a cold frosty morning the *vapour*, which would otherwise become *fog*, is turned to *hoar frost* on the ground.

Q. Why are FOGS more general in AUTUMN than in SPRING?

A. The *earth* in spring is not so *hot* as it is in autumn; in consequence of which its vapour is not chilled into fog as it issues into the air.

Q. Are FOGS more common in VALLEYS than on HILLS?

A. Yes; valleys containing more *moisture* than hills, and not being *exposed* to the *wind.*

Q. What is the cause of a BLACK MIST? and why does it bring WET weather?

A. The mist is *black*, because it is *overshadowed by dense clouds;* and *wet* weather may be expected, because the air is saturated with vapour.

Q. Why is MIST sometimes WHITE? and why does a white mist indicate FINE weather?

A. The mist is *white* because no *clouds blacken it with their shadow;* and *fine weather* may be expected because the sky is cloudless.

Q. Why do fogs generally appear to hover about CAPES and HEADLANDS of the sea-coast?

A. Because the soil of these places becomes *warmer in summer* than the ocean that washes their shores, but in the winter *colder;* and the *difference in temperature* is usually sufficient to produce a constant succession of fogs.

Q. Why do fogs appear over SHOALS and SANDBANKS of the ocean?

A. Because the water adjacent to these places is *colder* than that of the main ocean.

Q. Why do mists and fogs of great extent occur on the BANKS OF NEWFOUNDLAND?

A. A current of *warm water*, called the Gulf Stream, flowing from the tropics, encounters in this region a current of cold water flowing from the polar regions. The great differences in the temperature of the banks, the ocean, and the Gulf Stream, give rise therefore to almost constant fogs.

CHAPTER XXVI.

RAIN, SNOW, HAIL, FROST.

SECTION I.—RAIN.

Q. What is RAIN?

A. Rain is vapour *condensed in the air*, and precipitated to the earth in showers.

Q. In what MANNER is the vapour of the air CONDENSED so as to form rain?

A. When *two or more volumes* of humid air differing considerably in temperature *unite*, the several portions in union are incapable of absorbing the same amount of moisture that each could retain if they had not united. The excess of moisture, if very great, is precipitated as rain; if in slight amount, it appears as clouds, fogs, or mists.

Q. Upon WHAT LAW does this condensation of vapour and formation of rain depend?

A. Upon the law that the *capacity* of the air for *moisture decreases* in a greater ratio than the temperature.

Q. Why does RAIN fall in drops?

A. The particles of vapour, as they descend, unite with each other, and form into drops.

Q. What is the SIZE of rain-drops?

A. The size is varied by the rapidity with which the vapours are condensed.

Q. Why do CLOUDS FALL in RAINY weather?

A. 1. Because they are *heavy* with abundant vapour; and

2. The density of the air being *diminished*, is less able to buoy the clouds up.

Q. How do you KNOW that the DENSITY of the air is DIMINISHED in RAINY weather?

A. Because the mercury of a barometer *falls*.

Q. Does RAIN WATER possess any fertilising properties BESIDES that of mere MOISTURE?

A. Yes; rain water contains an abundance of *carbonic acid*, and

a small quantity of *ammonia*, to which much of its fertilising power may be attributed.

Ammonia is a compound of nitrogen and hydrogen. Common hartshorn is only ammonia and water.

Q. What EFFECT has RAIN upon the AIR?

A. It purifies it.

Q. In WHAT WAY?

A. By removing and dissolving injurious vapours, washing the air, setting in motion stagnant water, and mixing the air of the upper and lower regions.

Q. If paper is WETTED, it BLISTERS or PUCKERS: how is this?

A. The moisture (penetrating the paper) *drives its particles farther apart*, and (as the moisture is absorbed *unequally* by the paper) some parts are more enlarged than others; in consequence of which, the paper *blisters* or *puckers*.

Q. When the plants called TREFOIL, DANDELION, PIMPERNEL, &c., FOLD UP their LEAVES, RAIN is always close at hand: explain this.

A. 1. The cloudy weather diminishes the *light of the sun;* and without the stimulus of sunlight, these flowers never open their leaves.

2. The vapour of the damp air, insinuating itself into the air-vessels of these delicate plants, causes them to *expand;* in consequence of which, the leaflets contract and close.

All these plants close at sunset also.

Q. In which PART of the DAY does the MOST RAIN fall?

A. More rain falls by *night* than by day, because the cold of night *condenses the air*, and diminishes its capacity for holding vapour in solution.

Q. When do we have the MOST rain fall? in SUMMER or WINTER?

A. There are *more rainy days* from September to March, but the *heaviest rains* are between March and September.

Q. Can the air ABSORB MOISTURE at all temperatures, and retain it in an invisible state?

A. It can; and this power of the air is termed its *capacity of absorption*.

Q. How much MOISTURE can a VOLUME of air at 32° F. absorb?

A. An amount equal to the *hundred and sixtieth part of its own weight*.

Q. How does the CAPACITY of air for moisture increase with the temperature?

A. For every 27 additional degrees of heat, the quantity of moisture it can absorb at 32° is doubled. Thus a body of air at 32° F. absorbs the 160th part of its own weight; at 59° F., the 80th; at 86° F., the 40th; at 113° F., the 20th part of its own weight in moisture.

Q. In what SITUATIONS is the air always saturated?

A. Over the *ocean*, and upon the *adjacent coasts.*

Q. Where is the absolute HUMIDITY of the atmosphere the greatest?

A. In the *tropics*, where the temperature of the air, and its consequent capacity for moisture, is the greatest.

Q. What do we mean by ABSOLUTE HUMIDITY?

A. When we speak of the absolute humidity of the air, we have reference to the *quantity of moisture* contained in a given volume.

Q. What do we mean by RELATIVE HUMIDITY?

A. The dampness of the atmosphere, or its proximity to saturation. Relative humidity is a state dependent upon the mutual influence of absolute humidity and temperature; for a given volume of air may be made to pass from a state of dampness to one of extreme dryness, by merely elevating its temperature, and this, too, without altering the amount of moisture it contains in the least degree.

Q. What do we call an INSTRUMENT designed for measuring the HUMIDITY of the atmosphere?

A. A *Hygrometer;* that is, moisture measurer; from the Greek words which signify moist and measure.

Q. How may a SPONGE be made a HYGROMETER?

A. If a large sponge be dipped in *sea water*, and then squeezed *almost dry*, upon being balanced in a pair of scales suspended from a steady support, it will be found to preponderate or ascend according to the relative dampness or dryness of the weather.

Q. Why is it necessary, in order that the sponge should serve as a hygrometer, that it be previously dipped in SEA or SALT water?

A. Because the salt left in it from the water is a ready *absorbent of moisture.*

Q. How may the BEARD of the WILD OAT serve as a hygrometer?

A. The beard of the wild oat *twists around*, during atmospherical changes from dampness to dryness.

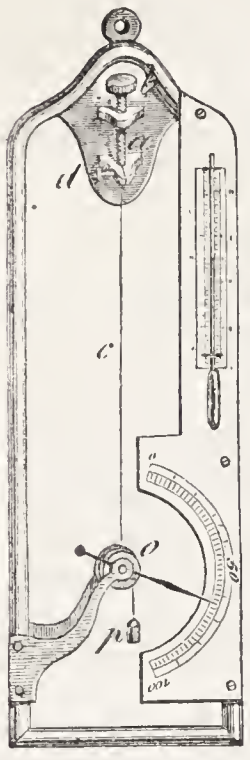
Q. How can a hygrometer be constructed of CATGUT?

A. If we fix against a wall a long piece of catgut, and hang a *weight* to the end of it, it will be observed, as the air becomes moist or dry, to *alter in length;* and by marking a scale, the two extremities of which are determined by observation when the air is very dry, and also when it is saturated with moisture, it will be found easy to measure the variations.

Q. What OTHER instruments have been invented for measuring the moisture in the air?

A. Several kinds of hygrometers are employed: those instruments which lengthen when they are moist, and shorten when they are dry, are called *absorption hygrometers.*

Fig. 86.

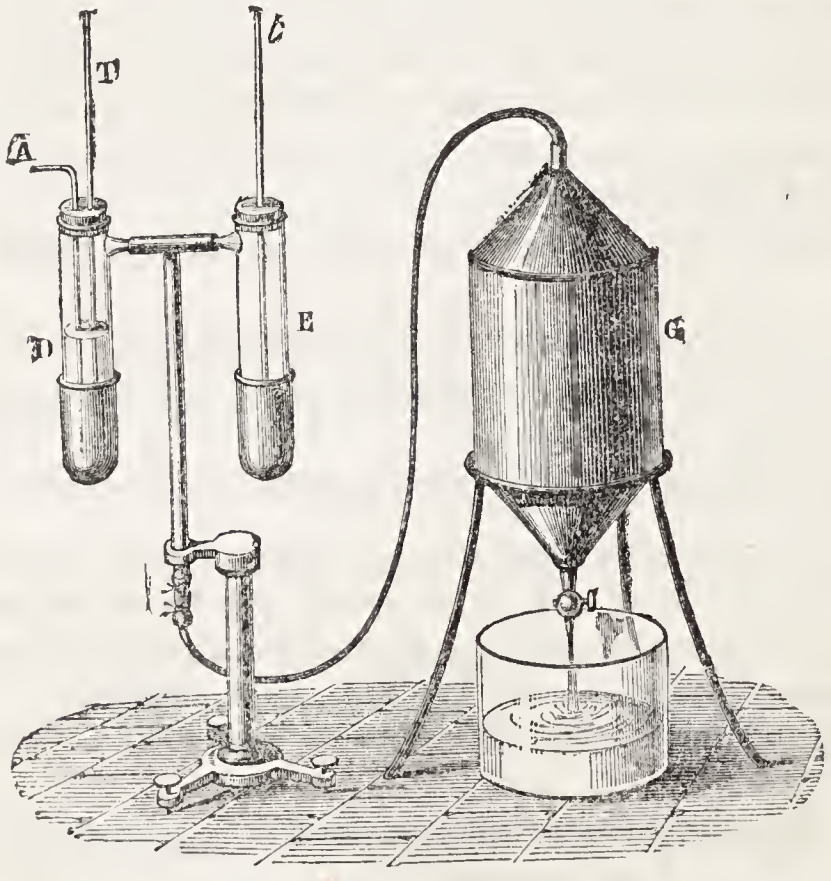


This instrument is made of a brass frame, on which a perfectly clean hair is stretched. This hair is supported at its upper end by a catch (*a*), fastened by a screw (*d*). The catch is raised or lowered by means of a screw (*b*). On its lower end it is wound on a pulley (*o*), to which it is fixed. This pulley has two grooves, on one of which the hair is fastened; and on the other, in a contrary direction to that of the hair, is a silk thread, which supports a small weight (*p*). An index, or hand, is moved by the pulley over a graduated scale. The amount of humidity in the atmosphere affects the length of the hair; when the hair is shortened, the index, or hand, is raised; when it lengthens, the weight (*p*) causes the index to descend. The graduated scale is marked from 0° to 100°. The first represents a perfectly dry atmosphere, and the latter an atmosphere saturated with vapour.

Q. What OTHER CONTRIVANCES are used for ascertaining the amount of MOISTURE in the AIR?

A. An apparatus called a *condensation hygrometer* was invented by M. Regnault, and has answered its purpose extremely well.

Fig. 87.



The apparatus in the diagram consists of two cups of polished silver, about two inches in height, and one across, or in *diameter*. In these cups two glass tubes are fixed, D and E; each of these tubes contain a thermometer, fastened by means of a cork. A tube A, passes through the cork in tube D: this tube is open at both ends, and is immersed in

the cup to the bottom. By means of a leaden pipe, the tube is put in communication with a vessel, G, full of water, and called an *exhauster*. The tube E contains a thermometer, but does not communicate with the exhauster. Under this arrangement some ether is poured into the tube D, until it is about half full; then the stop-cock of the exhauster is opened, the water escapes, and the air in the tube is rarefied. In consequence of the atmospheric pressure, the air then enters by the tube A; in doing so, passes through the ether, which it to some extent vaporises. When the process of cooling reaches the point at which dew is deposited, the thermometer T indicates the corresponding temperature, and we are then able to estimate the hygrometric state of the atmosphere.

Q. What is the CHIEF OBJECT answered by this apparatus?

A. By reducing the temperature of the common air, it shows at what point the vapour which it contains would be sufficient to saturate it.

Q. Is the moisture in the air GREATEST in the SUMMER or WINTER?

A. It is greatest in the *summer months*, and least in the *winter*.

Q. Where does RAIN fall MOST ABUNDANTLY?

A. Near the *equator;* the quantity decreases as we approach the poles.

Q. How many INCHES of RAIN fall yearly at the city of Vera Cruz, Mexico?

A. About two hundred and seventy-eight inches.

Q. How great a DEPTH of rain, measured in inches, falls YEARLY in London?

A. About twenty-five inches.

Q. How do you ACCOUNT for the great amount of rain falling at Vera Cruz?

A. Vera Cruz, situated within the tropics, is backed by *lofty mountains*, whose summits are covered with *perpetual snow;* against these the hot, humid air from the sea is driven by the trade-winds, condensed, and its excess of moisture is precipitated as rain.

Q. In what LATITUDES do the greatest number of rainy days occur?

A. There are more rainy days in the *temperate zones* than in the tropics, although the yearly quantity of rain falling in the latter districts is much greater than in the former.

Q. About how MANY rainy days are there in a year on the coast of England?

A. About one hundred and fifty-two, both on the east and west coasts.

Q. About how MANY rainy days are there in a year in the northern parts of the United States?

A. About one hundred and thirty-four; in the Southern States the number is somewhat less, being about one hundred and three.

Q. Why does it rain MORE FREQUENTLY in the TEMPERATE zones than in the tropics?

A. Because the temperate zones is a region of *variable winds*, and the temperature of the atmosphere changes often; while in the tropics the wind changes but rarely, and the temperature is very constant throughout a great part of the year.

Q. How is the AMOUNT of rain MEASURED?

A. By means of a *rain-gauge*.

Q. How is this CONSTRUCTED?

A. The best form consists of a *cylindrical metal vessel* furnished

with a float; the rain falling into the vessel raises the float, the stem of which is so graduated that the increase in depth can be very accurately measured.

Q. Why does it rain MORE upon the SEA-COAST than in the INTERIOR of a country?

A. Because the air adjacent to the ocean contains more *moisture* than the air inland.

Q. What is the average YEARLY FALL of rain in the tropics and temperate zones?

A. The average yearly fall of rain in the tropics is ninety-five inches; in the temperate zone only thirty-five.

The greatest rain-fall, however, is precipitated in the shortest time. Ninety-five inches fall in eighty days on the equator, while at St. Petersburg the yearly rain-fall is but seventeen inches, spread over a great number of days. Again, a tropical wet day is not continuously wet. The morning is clear; clouds form about ten o'clock; the rain begins at twelve, and pours till about half-past four: by sunset the clouds are gone, and the night is invariably fine.

Q. In the tropics, how are the seasons DIVIDED?

A. Into *wet* or *rainy*, and the *dry* season.

Q. When does the RAINY season of the tropics COMMENCE?

A. When the *trade-winds* or *monsoons* shift.

The following is the received explanation of the phenomena of the rainy seasons of the tropics: At a point $23\frac{1}{2}°$ north of the equator, at the tropic of Cancer, the vertical sun appears to stop when it is midsummer with us. As it moves southward our summer wanes; it crosses the equator, and appears to travel on until it has reached $23\frac{1}{2}°$ on the other side of the line, the tropic of Capricorn; then six months have passed; it is mid-winter with us, and midsummer with people in the southern hemisphere. The sun turns back (and the word tropic means the place of turning), retraces its course over the equator, and at the expiration of a twelvemonth is at our tropic again, bringing us summer. Now the rainy season is produced between the tropics by the powerful action of the sun, wherever it is nearly vertical, in producing vast quantities of vapour, which become condensed in the upper colder regions of the atmosphere, and dash to earth again as rain.

Q. Does the rainy season FOLLOW the SUN?

A. Yes; when the sun is *at* or *near* the *tropic of Cancer*, both before and after turning, all places near that tropic have their rainy season; when the sun makes a larger angle with their zenith, it has taken the rainy season with it to another place.

It is here obvious that a country between the tropics, and far from each, is passed over by the sun, in its apparent course, at two periods in the same year, with a decided interval between them. It must have, therefore, and does have, two rainy and two dry seasons.

Q. Are there any EXCEPTIONS to this order?

A. Yes; the parts of *Asia* and *Africa* bordering on the *Indian Ocean* are exceptions to this rule. These regions being under the influence of the *monsoons*, and not the *trade-winds*, the rainy season is somewhat *changed* in its character and seasons.

Q. Are not some countries entirely DESTITUTE of RAIN?

A. Yes; in some districts beyond the tropics, it never rains at all: thus, no rains fall in the Sahara, the Arabian and Persian Deserts; the great desert of Gobi; the shores of Peru and the arid regions of Mexico exhibit a similar character.

Q. WHY are these countries DESTITUTE of RAIN?

A. The cause of this scarcity is to be sought for in the *peculiar conformation of the country.*

In Peru, parallel to the coast, and at a short distance from the sea, is the lofty range of the Andes, the peaks of which are covered with perpetual snow and ice. The prevailing wind is an east wind, sweeping from the Atlantic to the Pacific across the continent of South America. As it approaches the west coast, it encounters this range of mountains, and becomes so cooled by them that it is forced to precipitate its moisture, and passes on to the coast almost devoid of moisture. In Egypt, and other desert countries, the dry sandy plains heat the atmosphere to such an extent, that it absorbs moisture, and precipitates none.

Q. Are there some districts in which it may be said to ALWAYS RAIN?

A. In some portions of *Guiana* it rains for a great portion of the year. The fierce heat of the tropical sun fills the atmosphere with *vapour*, which returns to the earth again in constant showers, as the cool winds of the ocean flow in from the higher latitudes.

Q. Does it ever rain WITHOUT CLOUDS?

A. *Several cases* are on record when this phenomena has taken place.

Q. What is the EXPLANATION of this phenomena?

A. Rain is produced by the *union of different portions of air at different temperatures.* The first effect generally produced is the formation of small globules of vapour, which accumulate and become clouds; these, condensed, give us rain. Now, two volumes of air heavily charged with vapour may unite under such circumstances that the moisture will be at once condensed into drops too heavy to float as vapour, in which case they will at once fall as rain, and no cloud will be produced.

Q. HOW GREAT a QUANTITY of water is supposed to be ANNUALLY PRECIPITATED as rain?

A. The amount is calculated to exceed *seven hundred and sixty million of tons.*

Q. Was this WHOLE AMOUNT raised by evaporation into the atmosphere?

A. Certainly; the daily amount of water raised by evaporation from the sea alone, amounts to no less than *one hundred and sixty-four cubic miles*, or about *sixty thousand cubic miles annually.*

Q. What is the DAILY AMOUNT of evaporation from the sea between the Cape of Good Hope and Calcutta?

A. During the months of *October* and *November*, it is known to average three-quarters of an inch daily from the whole surface.

Q. Is the climate of New England and the Northern United States DRIER than that of England and Central Europe?

A. *It is;* and this fact exercises an *important influence* upon many professions and callings. Painters find that their work dries quicker in New England than in Central Europe. Cabinet-makers in that country are obliged to use thicker glue, and watchmakers, animal instead of vegetable oil.

SECTION II.—SNOW.

Q. What is SNOW?

A. Snow is *congealed rain.*

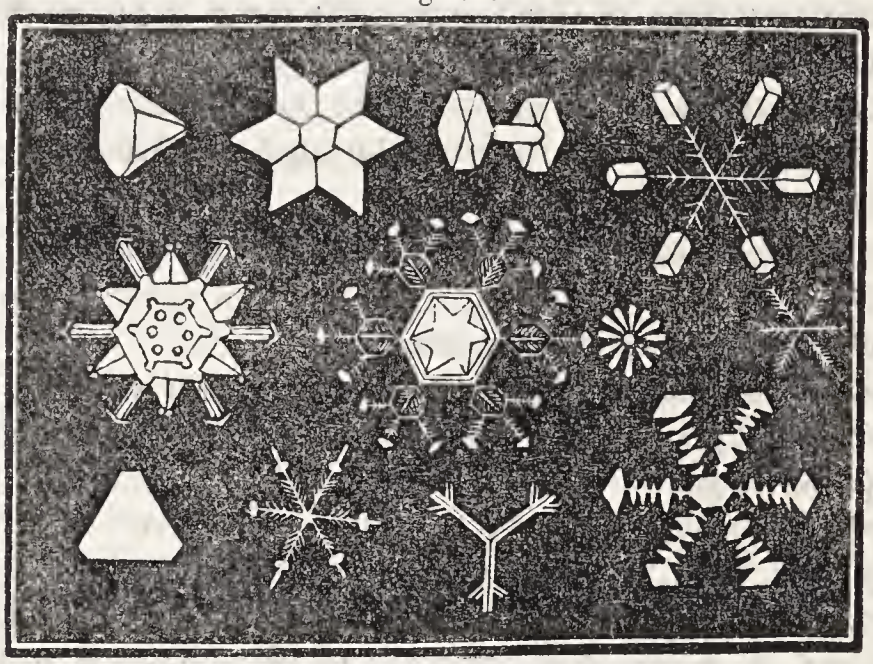
Q. Is snow nothing more than CONGEALED RAIN?

A. It is both *congealed* and *crystallised.*

Q. Is there any GREAT VARIETY of FORM, then, in the snow flakes?

A. Yes; in the Arctic regions *nearly a hundred different forms* of snow have been observed. (*See fig.* 88.)

Fig. 88.



FORMS OF SNOW FLAKES MAGNIFIED.

Q. How is SNOW OCCASIONED?

A. By the *cold air* (air below freezing point) *condensing* the vapour in the air.

Q. Are SLEET and SNOW the same?

A. Sleet is snow *partially melted.*

Q. How is SNOW PARTIALLY melted?

A. By *passing through a warmer current of air* as it *descends* to the earth.

Q. How does snow keep the surface of the earth WARM in WINTER time?

A. In consequence of its being a *bad conductor.*

Q. How does snow prove BENEFICIAL to the earth in the cold season?

A. It keeps the surface of the earth *warm*, protects vegetation to a considerable extent from the *cold*, and acts as a *fertiliser.*

Q. Why is snow a BAD CONDUCTOR of heat and cold?

A. Because *air* is confined among the crystals, and *air* is a very *bad* conductor; when, therefore, the earth is covered with snow, it cannot throw off its heat by radiation.

Q. Why is there no snow in SUMMER-TIME?

A. Because the *heat of the air* adjacent to the earth melts it in its descent, and prevents it from reaching the surface of the earth.

Q. Why is SNOW WHITE?

A. Because it is formed of an infinite number of very minute crystals and prisms, which reflect all the colours of the rays of light from different points, and these colours, *uniting* before they meet the eye, cause snow to appear white.

Q. Under what circumstances does snow fall in LARGE FLAKES, and when in SMALL?

A. The largest flakes are formed when the air *abounds with vapour*, and the temperature is about 32° F.; but as the moisture diminishes, and the cold increases, the snow becomes finer.

Q. What is the SNOW FLAKE composed of?

A. *Regular* and *symmetrical crystals*, having a great diversity of forms, as may be seen in *fig.* 88.

Q. Do we see the SAME crystals in ICE?

A. They exist in ice, but are so *blended together* that their *symmetry is lost* in the compact mass.

Q. Is the BULK of SNOW GREATER than that of water?

A. The bulk of recently fallen snow is *ten or twelve times greater* than that of water.

Q. Does snow ever occur of any other appearance than WHITE?

A. *Yes;* in the Arctic regions and on some mountains it is *red*, and occasionally *green*.

Q. What is the CAUSE of these appearances?

A. These singular hues are occasioned by little *microscopic plants*, which germinate and live in the snow. They consist of little globules from $\frac{1}{1000}$ of an inch to $\frac{1}{3000}$ of an inch. Each globule is divided into seven or eight cells, filled with a liquid, which gives a colour to the snow, and is sometimes green and sometimes red.

SECTION III.—HEAT.

Q. What is HAIL?

A. *Frozen rain.*

Q. What makes ONE part of the air colder than another?

A. It is frequently caused by *electricity unequally distributed* in the air.

Q. How can ELECTRICITY make air COLD?

A. Air, when *electrified*, is *expanded*, and *expansion* produces *cold.*

Q. When is hail most FREQUENT?

A. In *summer* and *autumn.*

Q. WHY in SUMMER and AUTUMN?

A. Because the air then is more *electrical*, and the vapours *rising higher* than at other times of the year, are in consequence *much colder.*

Q. Is not hail often PRECEDED OR ATTENDED by THUNDER?

A. Thunderstorms frequently accompany heavy falls of hail, the *congelation* of the water *disturbing the electricity* of the air.

Q. What is the FORM and STRUCTURE of the hailstone?

A. Hailstones are generally *pear-shaped*, and if they are divided through the centre, they will be found to be composed of alternate layers of ice and snow, arranged around a nucleus, like the coats of an onion.

"*Nucleus*"—the kernel, anything about which matter is gathered.

Q. What is the SIZE of hail generally?

A. Hail varies in size from stones as small as a *pea* to those which are *several inches in circumference.*

Q. WHERE do hail-storms most FREQUENTLY occur?

A. In *temperate climes* most frequently, and rarely within the tropics.

Q. In what LOCALITIES in the temperate zones do hail-storms occur most frequently?

A. In the *vicinity of high mountains*, whose peaks are always covered with ice and snow. The south of France, which lies between the Alps and Pyrenees, is annually ravaged by hail; and the damage which it causes yearly to vineyards and standing crops is estimated at upwards of two millions of money.

Q. Is the occurrence and formation of hail CLEARLY UNDERSTOOD?

A. It is *not;* much information exists upon the subject, but no theory has yet been formed which satisfactorily accounts for all the facts which have been observed.

SECTION IV.—GLACIERS, ICEBERGS, AND FROST.

Q. What are GLACIERS?

A. Huge masses of ice which are in the valleys of snow-capped mountains: such as the Alps, Mont Blanc, &c.

Q. How are they PRODUCED?

A. By the alternate melting and freezing of the snow during the frequent changes of temperature.

Q. How MANY of these glaciers are said to exist in the ALPS?

A. About four hundred between Mont Blanc and the Tyrol.

Q. What SIZE are they?

A. Some of them are fifteen or eighteen miles long. One is estimated at a hundred square miles.

Q. What is the APPEARANCE of these glaciers?

A. They sometimes present the appearance of a field of ice; at others that of the waves of the ocean; at others that of rugged rocks.

Q. Are not SOME glaciers covered with stones and earth?

A. Yes; these have been torn away from the surrounding declivities, and thus a wall of ruin is found on the edge of the glaciers.

Q. What are these RUINS called?

A. *Moraines.*

Q. Are these MORAINES moved by the glacier?

A. Yes; these rocky masses are moved onward by the glaciers, and are finally deposited in what is called a terminal moraine.

Fig. 89.

In the above engraving is represented what is called a glacier table, on the Mer de Glace of Chamouni. It is a magnificent slab of granite, measuring twenty-three feet in length, seventeen in breadth, and about three feet and a half in thickness. It appears as if it had been elevated above the level of the glacier, and is supported by a rude pedestal of icy marble. It is probable that what appears as an elevation is only the result of circumstances. Once upon a time, the whole glacier bearing that huge piece of granite was at one level; but the rain and the sun have carried away the other parts of the glacier, and only that part which is protected by the stone from heat and wet has been preserved.

Q. What is an ICEBERG?

A. Masses of ice that float in the sea.

Q. How are these ICEBERGS FORMED?

A. They are supposed to be glaciers which have glided to the sea-shore from the mountains, and been drifted away by the waves.

Q. Would this ACCOUNT for their VAST DIMENSIONS?

A. These broken masses of glacier have been added to by the accumulation of snow and frozen rain, and are continually increasing in size.

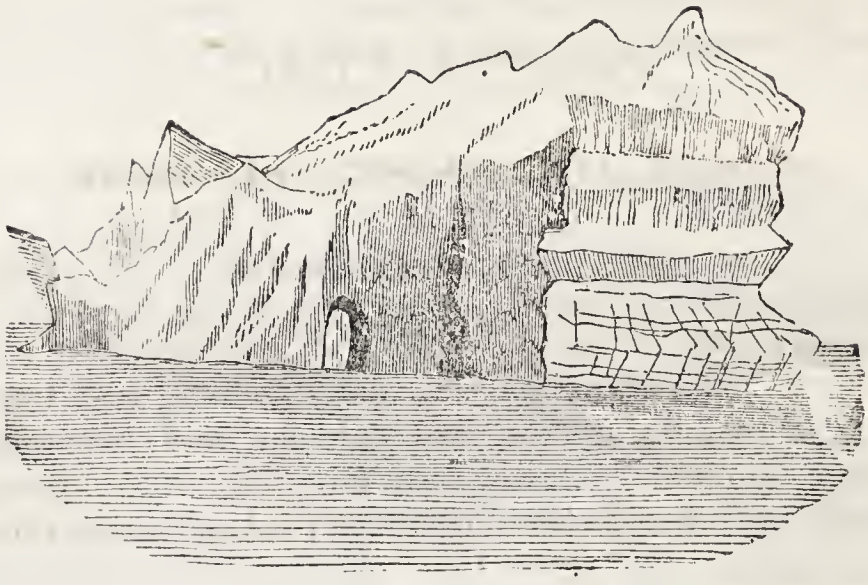
Q. How is it that they do NOT MELT?

A. The temperature where icebergs are found is rarely above freezing point, even in the height of summer.

Q. What is the average HEIGHT of icebergs?

A. Fully formed icebergs vary in height above the water from 180 to 210 feet; but the mass of ice below the water is seven or eight times as great as that which is seen above.

Fig. 90.



AN ICEBERG.

Q. Is there any DIFFERENCE in the description of HOAR FROST ?

A. Yes; frozen dew and frozen fog are both varieties of hoar-frost.

Q. What is FROZEN DEW usually called ?

A. Ground hoar-frost.

Q. How is it PRODUCED ?

A. By rapid radiation of heat from the earth.

Q. In WHAT WAY does this rapid radiation cause HOAR-FROST ?

A. It cools down the surface of the ground to so low a temperature, that it freezes the dew upon it.

Q. When is hoar frost MOST OBSERVABLE ?

A. After a very clear night.

Q. On what ACCOUNT ?

A. On a very clear night the radiation is more rapid, and the vapour or dew consequently freezes more quickly.

Q. What is the cause of that hoar frost which arises from FROZEN FOG ?

A. The thick fog which invested the earth during the night (being condensed by the cold frost of early morning) is *congealed* upon *every object* with which it comes in contact.

Q. Why are not the crystals of frost and snow TRANSPARENT like ice ?

A. The crystals of frost and snow are *not solid*, but they contain air; hence their brilliant whiteness: for the air, preventing the ready transmission of light through the crystals, the rays are copiously reflected from the mass of crystals.

Q. Why is the darkness of night DIMINISHED by the presence of SNOW ?

A. Because the snow *reflects*, instead of *absorbing*, like the bare ground, the faint light that proceeds from the sky.

CHAPTER XXVII.

LUMINOUS ATMOSPHERIC PHENOMENA.

SECTION I.—METEORITES.

Q. What are METEORITES?

A. Meteorites are *solid, luminous bodies* which from time to time visit the earth, moving with immense velocity, and remaining visible but for a few moments. They are generally accompanied by a luminous train, and during their progress explosions are often heard.

Q. What is an AEROLITE?

A. The term aerolite is given to those *stony masses* of matter which are sometimes seen to fall from the atmosphere.

It is derived from the Greek words αερ (atmosphere), and λιθος (a stone). A meteor is distinguished from an aerolite by the fact that it bursts in the atmosphere, and disperses in a vapour-like smoke; while the aerolite, which is supposed to be a fragment of a meteor, comes to the ground.

Q. What is the WEIGHT of those aerolites which have been known to fall from the atmosphere?

A. Their weights vary from a *few ounces* to *several hundred pounds*, or even *tons*.

Q. At what HEIGHT in the atmosphere are meteors supposed to appear?

A. Their height above the earth has been estimated to vary from *eighteen to eighty miles.*

Q. With what VELOCITY do they move?

A. The velocity of these bodies is somewhat more than *three hundred miles per minute*, though one meteor of immense size, which is supposed to have passed within *twenty-five miles* of the earth, moved at the rate of *twelve hundred miles per minute.*

Q. How can the HEIGHT of these bodies in the atmosphere be DETERMINED?

A. If a body in the atmosphere is seen by two observers at the same time from different stations, and its angular elevation taken at both stations, its height in miles and feet is easily ascertained by *trigonometry*, when the distance between the two stations is known.

Q. How can its SPEED be ascertained?

A. By dividing the length of its visible path (which is ascertained by noticing its points of appearance and disappearance) by the number of seconds during which the body is seen.

Q. What is the VALUE of such estimates?

A. Owing to the short time the meteor is visible and its great velocity, accurate observations cannot be made upon it; and all estimates respecting their distance, size, &c., must be considered as only *near to the truth.*

Q. What is the general FORM and APPEARANCE of aerolites?

A. Most of them have a *pyramidal form*, and appear covered with a *black shining crust*, as if the body had been coated with pitch. When broken, their colour is ash-gray, inclining to black.

Very many of the meteorites which have fallen at different times and in different parts of the globe, resemble each other so closely, that they would seem to have been broken from the same piece or mass of matter.

Q. What is their COMPOSITION?

A. Great numbers of aerolites have been analysed, and found to contain *nineteen or twenty different elementary substances.* But for the most part they consist of *malleable iron and nickel.*

Q. Do the aerolites resemble in composition any OTHER BODIES upon the surface of the earth?

A. They *do not;* malleable iron is *rarely*, if ever, found in *earthy substances;* and metallic nickel does not occur upon the surface of the earth naturally.

Q. What is PECULIAR to the composition of METEORIC iron?

A. It has a highly *crystalline arrangement* so peculiar that it is especially distinguished by it. This arrangement of its particles enables us to decide upon the meteoric origin of masses of iron which are occasionally found scattered up and down the surface of the earth.

Q. WHERE have such masses been found?

A. In the *South of Africa*, in *Mexico*, *Siberia*, and on the *route* overland to California. Some of these masses are of immense weight, and undoubtedly fell from the atmosphere.

Q. How are meteorites supposed to ORIGINATE?

A. *Four suggestions* have been advanced to account for the origin of these extraordinary bodies: 1. That they are thrown up from *terrestrial volcanoes.* 2. That they are produced in the atmosphere from *vapours and gases* exhaled from the earth. 3. That they are thrown from *volcanoes in the moon.* 4. That they are of the *same nature as the planets*, either derived from them, or existing independently.

Q. Which of these suggestions is regarded as MOST PROBABLE?

A. The *fourth* most fully explains the facts connected with the appearance of meteorites, and the *third* likewise has some *strong evidence* in its favour.

Q. In what respect do SHOOTING STARS differ from METEORS?

A. Their altitude and velocity are *greater*, they are far *more numerous and frequent*, and are *unaccompanied* by any *sound* or *explosion.* Their brilliancy is also much *inferior* to that of the *meteor;* and no portion of their substance is ever known to have reached the earth.

Q. What do we know concerning their HEIGHT?

A. Owing to their greater number and frequency of occurrence, many careful observations have been made upon them; their height is supposed to vary from six to four hundred and sixty miles, the greatest number appearing at a height of about seventy miles.

Q. What is their supposed VELOCITY?

A. It is supposed to range from sixty to fifteen hundred miles per minute.

Q. Are meteors and shooting stars at ALL TIMES EQUALLY ABUNDANT?

A. They are *not;* some may be seen occasionally on a clear night, but they appear to return at certain fixed times, when they descend literally in showers.

Q. What are the PERIODS when they may be noticed most ABUNDANTLY?

A. In the early part of *August*, and the middle of *November.*

Remarkable falls of aerolites were observed at Barbotan, in France, on the 24th of July, 1790; at Vienna, in Italy, on June 16th, 1794; in Connecticut, U.S., on the 14th of December, 1807; and at Ardèche, in France, on June 15th, 1821.

Q. How MANY very remarkable meteoric showers have been noticed?

A. Four: in 1799, 1822, 1831, and 1833—all in the month of *November.* In the shower of 1833, the meteors in many parts of the United States appeared to fall as thick as snow-flakes.

Q. Do the shooting stars appear to emanate from any particular part of the heavens?

A. The majority seem to start from a point in the constellation of Leo, and undoubtedly far beyond the limits of our atmosphere.

Q. What THEORY has been proposed by Professor Olmsted to account for the origin and appearance of shooting stars?

A. That the *source* of these *appearances* is a body composed of matter exceedingly rare, like the tail of a comet, revolving round the sun within the orbit of the earth in a space little less than a year; that at times the body approaches so near to the earth that the extreme portions become detached and drawn to the earth, by virtue of its great attraction. It further supposes that the matter of which these bodies are composed is combustible, and becomes ignited on entering the earth's atmosphere.

Q. Supposing this theory to be true, with what VELOCITY would these bodies detached from the main mass enter our atmosphere?

A. The nearest point of approach of the central body to the earth is supposed to be about *two thousand miles.* Bodies falling from this distance would enter the atmosphere at a distance of at least fifty miles from the earth, with a velocity generated by the force of gravity alone of four miles per second—a velocity ten times greater than the utmost speed of a cannon ball.

Q. Why would the fragments necessarily TAKE FIRE on entering the earth's atmosphere?

A. When air is *quickly compressed* in a tight cylinder to the extent of one-fifth of its volume, sufficient heat is generated to *ignite tinder.* If we suppose that the fragments descend with such velocity as to compress the rarefied atmosphere at the height of thirty miles to such an extent only as to make it as dense as ordinary air, the temperature would be raised as high as 46,000° Fahrenheit—a heat far more intense than can be generated in any furnace.

Q. What OTHER THEORY has been proposed in relation to the origin of these bodies ?

A. That of *Chaldini*, who supposes that, in addition to the planets and their satellites which revolve about the sun, there are innumerable smaller bodies; and that these occasionally enter within the atmosphere of the earth, *take fire*, or descend to its surface.

Q. What is the ZODIACAL LIGHT ?

A. It is a *singular luminous* appearance seen in the horizon before sunrise and after sunset, most conspicuously in the months of April and May.

Observations made during the year 1855 seem to conclusively prove that the appearance known as the "zodiacal light" is occasioned by a ring of nebulous matter encircling and pertaining to the earth.

SECTION II.—THE AURORA BOREALIS.

Q. What are the NORTHERN LIGHTS ?

A. *Flashes of light*, of various colours, occasionally seen in the sky at night, and properly called aurora borealis.

Q. What is SUPPOSED to be the CAUSE of this phenomenon ?

A. *Electricity* in the higher regions of the atmosphere.

Q. Is the aurora ever seen in OTHER PARTS of the heavens than towards the north ?

A. In the northern hemisphere it always appears in the *north*, but in the southern hemisphere it appears in the *south:* it seems to originate at or near the poles of the earth, and is consequently seen in its greatest perfection within the arctic and antarctic circles.

Q. What is KNOWN concerning the EXTENT of the aurora ?

A. It is not *local*, but is seen simultaneously at places widely remote from each other, as in Europe and America.

Q. What FORMS are generally assumed by the aurora ?

A. It appears sometimes as a dark segment, as a corona or crown of light, as an arch, or in the form of luminous streamers.

Q. What CALCULATIONS have been made respecting the height of the aurora ?

A. The height of the appearances varies from *one* to *two hundred miles;* they sometimes appear within the region of the clouds, and very near to the earth.

Q. Do any SOUNDS ever attend the appearances of the aurora ?

A. It has been often asserted, and on good authority, that sounds have been heard attending the phenomena of the aurora, like the *rustling of silk*, or the sound and *crackling of a fire.* On this point, however, there is great difference of opinion.

Q. Do the auroras appear at any PARTICULAR SEASONS and times ?

A. They appear more frequently in the *winter* than in the summer, and are only seen at *night.*

Q. Do they also occur in the DAY-TIME ?

A. The aurora is known to *affect the magnetic needle* and the

telegraph; and as the effects upon these instruments are noticed by day as well as by night, there can be no doubt of the occurrence of the aurora at all hours. The intense light of the sun renders the auroral light invisible during the day.

Q. Of what UTILITY are the auroral appearances in the polar regions?

A. During the long polar night, when the sun is absent, the aurora appears with a magnificence unknown in other regions, and affords *light sufficient* for many of the *ordinary out-door employments.*

Fig. 91.

The accompanying figure represents one of the most beautiful of the auroral phenomena.

Q. Are the auroras subject to any other VARIATIONS in their appearance?

A. They appear to be subjected to a *variation* extending through a *cycle of years;* thus from 1705 to 1752 the northern lights became more and more frequent; but after that, for a period, they were seen but rarely. In 1820 an increase in the frequency of these phenomena took place, and of late years their brilliancy has been very great.

CHAPTER XXVIII.

POPULAR OPINIONS CONCERNING THE WEATHER.

Q. Do the general meteorological changes which take place almost daily, and which are designated as weather changes, occur in accordance with certain FIXED LAWS?

A. There is no reason to doubt that every change in the weather is in strict accordance with some *certain physical agencies*, which are fixed and certain in their operations.

Q. Why can we not, then, with certainty determine and foretell the CHARACTER of the weather for any particular time?

A. Because the laws which govern meteorological changes are as yet *imperfectly understood.*

Q. Is there any reason for supposing that the moon has any INFLUENCE upon the weather?

A. An examination of meteorological records, kept in different countries, through many years, proves conclusively that the popular notions concerning the influence of the lunar phases on the weather have *no foundation* in any *well-established theory*, and no correspondence with observed facts.

Q. Do meteorological records afford any support to the belief in the occurrence of RAIN at particular PHASES of the moon?

A. There is some reason for supposing that rain falls more frequently about *four days before full moon*, and less frequently about four or five days before new moon, than at other parts of the month; but this cannot be considered as an established fact: in other respects the changes of the moon cannot be shown to have influenced in any way the production of rain.

Q. It is a current belief among many persons that all timber should be felled during a decline of the moon: is there any FOUNDATION for this belief?

A. Some years since (this belief being one received in many different countries) an experiment on an extensive scale was made in France, by an eminent agriculturalist, to test the matter; and it was found that there was *no difference* in the quality of any timber felled in different parts of the lunar month.

Q. Does the bright moonlight in any way hasten the PUTREFACTION of ANIMAL or VEGETABLE SUBSTANCES?

A. It is generally supposed to do so; but the fact is, that on bright, clear nights, when the moon shines brilliantly, *dew* is more *freely deposited* on these substances than at other times, and in this way putrefaction may be accelerated. With this the moon has no connection.

Q. Is there any FOUNDATION for the belief that the appearance of the aurora borealis is followed by a CHANGE in the weather?

A. Meteorological registers conclusively show that there is *no such connection*, and that the appearance of the aurora is as often followed by fair weather as by foul.

Q. Is there any TRUTH in the traditional notion that a long and violent storm usually accompanies the period of the EQUINOXES?

A. The examination of weather-records for sixty-four years show that *no particular day* can be pointed out in the month of September (when the "equinoctial storm" is said to occur) upon which there ever was, or ever will be, a so-called equinoctial storm. The fact, however, should not be concealed, that taking the average of the five days embracing the equinox for the period above stated, the amount of rain is greater than for any other five days, *by three per cent.*, throughout the month.

Q. Is there any REASON for believing that cold and warm seasons ALTERNATE

A. Meteorological records, kept for eighty years at the observatory of Greenwich, seem to show that groups of *warm years alternate with cold ones* in such a way as to render it most probable that the mean annual temperatures rise and fall in a series of curves, corresponding to periods of *about fourteen years.*

Q. Is it PROBABLE that some ANIMALS and INSECTS are able to FORETELL changes in the weather before MAN can perceive any indications of the same?

A. Of this fact there appears to be *no doubt.* Some varieties of the land snail only make their appearance *before a rain.* Some other varieties of land crustaceous (shelly) animals change their colour and appearance twenty-four hours before a rain.

Q. What curious fact has been noticed in respect to the LEAVES of TREES indicating changes in the weather?

A. For a light, short rain, some trees have been observed to *incline their leaves*, so as to *retain water;* but for a long rain, they are so doubled as to conduct the water away.

Q. What FACT has also been noticed respecting the changes in SPRINGS previous to a rain?

A. The water of springs has been observed to rise and flow out in greater volume *previous to a rain.*

Most, if not all, of the popular proverbs respecting changes in the weather, the influence of the moon, of frosts, auroras, and the like, when tested by observation, will be found to be unsupported by facts, and unworthy of the slightest credence.

"HE THAT OBSERVETH THE WINDS SHALL NOT SOW; AND HE THAT REGARDETH THE CLOUDS SHALL NOT REAP." (Eccles. xi. 4.)

LIGHT AND ACTINISM.

CHAPTER XXIX.

LIGHT.

Q. What is LIGHT?

A. Light is supposed to be caused by the *undulations* or *waves* in, or *vibrations* of, an *elastic fluid* pervading all space, called ether. These undulations or vibrations reaching the eye, affect the optic nerve, and produce the sensation which we call light.

Q. What is that SCIENCE CALLED which treats of vision, and the properties and phenomena of light?

A. The science of *optics.* This term is derived from the Greek word which signifies seeing.

Q. What ANALOGY is there between the eye and the ear?

A. The vibrations or undulations of the *ether* pass along the space intervening between the visible object and the eye, in the *same man-*

ner that the undulations of the *air*, produced by a sounding body, pass through the air between this body and the ear.

Q. What is the THEORY which in this manner accounts for the origin of light called?

A. The *undulatory theory.*

Q. Is there any OTHER THEORY according to which the phenomena of light are explained and accounted for?

A. Some suppose that a distant object becomes visible to us by *emitting particles of matter* from its surface, which particles of matter, passing through the intervening space between the visible object and the eye, *enter* the *eye*, and, striking upon the *nervous membrane*, so affect it as to produce the sensation of light or vision.

Q. By what NAME has this theory been designated?

A. The *corpuscular theory:* from *corpuscle*, an atom.

Q. What ANALOGY, according to this theory, exists between the eye and the organs of smelling?

A. We recognise the odour of an object in consequence of *material particles* passing from the object to the organs of smelling, and there producing an effect. In the same manner, a visible object at any distance may be supposed to send forth *particles of matter*, which move to the eye, and produce *vision*, acting mechanically on its membrane in the same manner as the odour of a rose produces a physical effect on the organs of smelling.

Q. Which of these two theories is now generally RECEIVED by scientific men?

A. The *first*, or *undulatory theory*, because more of the phenomena of light can be satisfactorily explained by it than by the corpuscular theory. In some respects the undulatory theory is not satisfactory, and some phenomena cannot be perfectly explained by either theory.

Q. If the corpuscular theory be correct, how LARGE a SPACE will a common candle fill with particles of luminous matter?

A. A common candle can fill for hours a space *four miles in diameter*, as it would be visible, under favourable circumstances, in every portion of this space.

Q. If we collect a large quantity of light in one point by means of a glass, and throw it upon the most sensitive balance, does it indicate any PERCEPTIBLE WEIGHT?

A. It does *not*, in the *slightest degree.*

Q. What are the chief SOURCES of light?

A. The *sun*, the *stars*, *fire* or *combustion*, *electricity*, and *phosphorescence.*

Q. How does COMBUSTION make undulations of light?

A. The atoms of matter (set in motion by heat), *striking against* the ether, produce *undulations* in it; as a *stone* thrown into a stream produces undulations in the *water.*

Q. With what VELOCITY does light move through space?

A. With a velocity of *one hundred and ninety-two thousand miles* in a *second* of time.

Q. Does ALL light travel equally fast?

A. Yes; the light of the sun, the light of a candle, or the light from houses, trees, and fields.

Q. How LONG a TIME does it require for light to pass from the sun to the earth?

A. *Eight minutes and thirteen seconds.*

Q. How long in travelling from the planet URANUS to the earth?

A. About *three hours.*

Q. How much time is required for a ray of light to traverse the space intervening between the nearest FIXED STARS and the earth?

A. More than *six years;* and from the farthest cluster of stars, hundreds of years will be required.

Q. What, therefore, would be the CONSEQUENCE if one of the remote fixed stars were to-day "blotted from the heavens?"

A. Several *generations* of the earth would *pass away* before the obliteration could be known to man.

Q. In what MANNER does the moon, and the planets belonging to the solar system, GIVE LIGHT?

A. They shine only by means of the *sun's light*, which is *reflected* from their surfaces.

Q. Where does the LIGHT of HOUSES, TREES, and FIELDS come from?

A. The light of the *sun* (or of some lamp or candle) is *reflected* from their *surfaces.*

Q. Why are SOME surfaces DULL and OTHERS BRILLIANT?

A. Those surfaces which *reflect the most light* are the most *brilliant;* and those which *absorb* light are *dull.*

Q. By WHOM, and in what MANNER, was the velocity of light first ascertained?

A. By *Von Roemer*, an eminent Danish astronomer, from *observations* on the *satellites or moons of Jupiter.*

Q. How would the INSTANTANEOUS TRANSMISSION of light through space enable us to see the heavenly bodies in different parts of the earth's orbit?

A. If the transmission of light were instantaneous, it must be obvious that the reflected light of the sun would take up *no more time* in passing from any one of the planetary bodies to the earth, when they are *farthest* from us, than it does when they are *nearest;* and as the situation of the earth with respect to the planets is different in different parts of her orbit, the satellites of Jupiter, on emerging from the shadow of that planet, would be seen as quickly when the earth was in one part of her orbit as in another.

Q. Has the velocity of light been determined in OTHER WAYS?

A. It *has;* and the results *uniformly agree* with the velocity announced by Von Roemer.

Q. How does the velocity of light COMPARE with the speed of a locomotive?

A. Light passes from the sun to the earth in about *eight minutes;* a locomotive engine, travelling at the rate of a mile in a minute, would require upwards of *one hundred and eighty* years to accomplish the same journey.

Q. How does the light of SIRIUS, one of the brightest of the fixed stars, compare with the light of the sun?

A. Dr. Wollaston has calculated that it would require *twenty thousand millions* of the brightest stars like Sirius to equal the light of the sun, or that that orb must be *one hundred and forty thousand* times farther from us than he is at present, to be reduced to the illuminating power of Sirius.

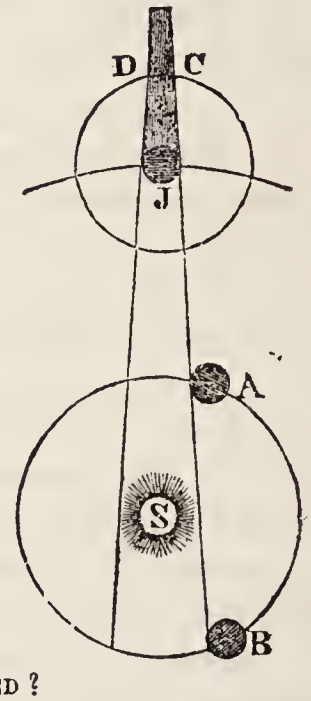
Q. How does the light of the FULL MOON compare with that of the sun?

A. It is estimated to be *three hundred thousand* times weaker than sunlight.

Q. What did Von Roemer find to be the FACT in regard to Jupiter's satellites?

A. He found that the effect of the transmission of light was such, that when the earth is between Jupiter and the sun, the satellites, after being eclipsed, are perceived rather more than *eight minutes sooner* than they ought to appear according to the time as calculated by the most accurate tables; and when the earth is in the opposite part of her orbit, so that the sun is between this planet and Jupiter, the satellites emerge about *eight minutes later* than the calculated or mean time.

Fig. 92.



Hence it will be apparent that light takes up eight minutes in passing through a space equal to half the diameter of the earth's orbit, or the distance between the earth and the sun, which is ninety-five millions of miles; so that it moves at the rate of nearly 200,000 miles in one second.

In the annexed diagram (*fig.* 92) let S represent the sun, A and B the earth in different parts of her orbit; J, Jupiter; D, his nearest satellite entering the shadow of that planet; and C the same satellite emerging from the shadow. Now the time of the commencement or termination of an eclipse of the satellite, as stated from calculation in tables, is the instant at which the satellite would appear to enter or emerge from the shadow, if it could be seen by an observer from the sun; and it is found, from repeated observation, that the eclipse takes place about eight minutes earlier than the calculated period, when the earth is in the nearest part of her orbit, as at A, and eight minutes later when she is in the opposite part of her orbit, as at B.

Q. What do we mean when we speak of light being REFLECTED?

A. When a ray of light strikes against a surface, and is caused to *turn back* or *rebound* in a direction different from whence it proceeded, it is said to be *reflected*.

Q. When is light said to be ABSORBED?

A. When its rays are *retained* upon the surface upon which they fall they are said to be absorbed; in consequence of which their presence is not made sensible by *reflection*.

Q. What curious EXPERIMENT has recently been made, tending to show that light is really a refined sort of matter?

A. By the aid of very delicate instruments, it can be shown that

a ray of light is *bent* out of its *right line* wherever a solid body (as a knife edge) is made to cut the edge of the beam.

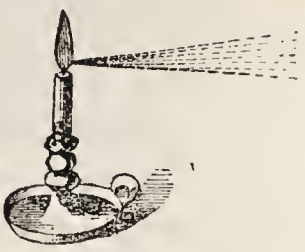
Q. What is the CAUSE of strabismus, or squinting?

A. The *inability* of one eye to follow the *motions* of the other; this may arise from habit, imperfect power in one eye, or some defect in the muscular movements.

Q. In what manner is light PROPAGATED?

A. In *right lines* from every luminous point, every such line being called a *ray* of light.

Fig. 93.



Q. What do we mean by a PENCIL of light?

A. A *collection of radiating lines* or rays, as seen in *fig.* 93.

Q. Upon what CIRCUMSTANCES does the degree of illuminating power of any body depend?

A. Upon the *intensity* of the exciting power in the luminous body; the distance of the illuminating body; the amount of *absorption* which the rays undergo in traversing the intervening media; and the *angle* at which the rays fall upon the surface.

Q. In artificial light, upon what does the illuminating power DEPEND?

A. Upon the *quantity of solid matter* which changes form. Pure hydrogen gas burns freely, but emits little light; if the vapour of turpentine, containing carbon, be added to it, it burns with great brilliancy.

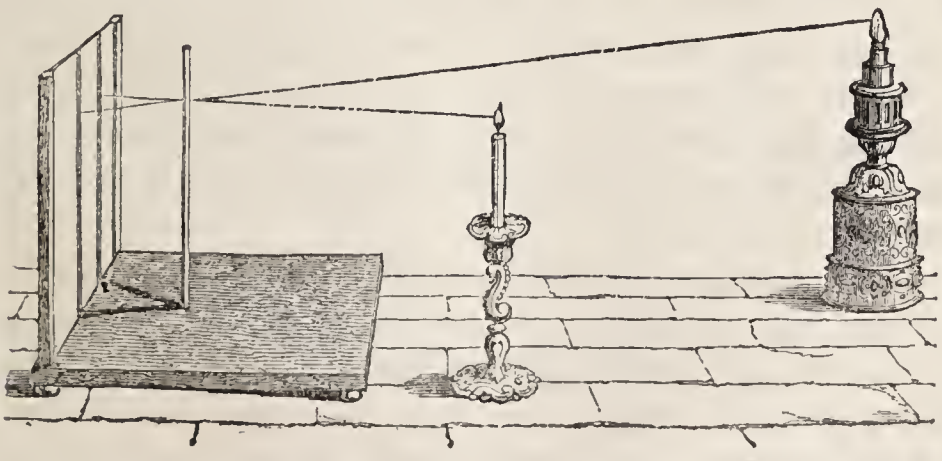
Q. How is the INTENSITY of light proceeding from various sources MEASURED and COMPARED?

A. By means of an instrument called a *photometer*.

Q. By what SIMPLE CONTRIVANCE may the relative illuminating powers of different lights be COMPARED?

A. If we allow the *shadows* from a single object to fall upon a *white screen*, and then remove the sources of light from or towards

Fig. 94.



it until all the shadows are of the same intensity, the *distances* at which the illuminating bodies are from the screen will express the *relative intensity* of the light of each. (*See fig.* 94.)

Q. Can ANY NUMBER of rays of light CROSS each other in the same space without jostling or interfering?

A. They *can.*

Q. How can you PROVE this?

A. If a *small hole* be made from one room to another through a *thin screen*, any number of candles in one room will shine through this hole, and illuminate as many *spots* in the other room as there are candles in this, all their rays *crossing* in the *same hole*, without hindrance or diminution of intensity.

Q. What is DARKNESS?

A. The *absence of light.*

Q. What is a SHADOW?

A. A shadow is the name given to the *comparative darkness* of places or objects, which are *prevented* by intervening things from receiving the *direct rays* of some luminous body shining on the objects around.

Q. What is the apparent darkness of a shadow PROPORTIONAL to?

A. It is proportional to the *intensity* of the *surrounding lights;* thus, a finger held between a candle and the wall casts a shadow of a certain intensity; if another candle be placed in the same line from the shadow, the shadow will appear doubly dark, although, in fact, more light will be reaching it, and reaching the eye from it than before; it will be more dark only by comparison.

Q. Why cannot we see through a CROOKED TUBE as well as through a STRAIGHT one?

A. Because light moves only in *straight lines.*

Q. What is the PHILOSOPHY of taking aim with a gun or arrow?

A. In taking aim with a gun or arrow, we proceed upon the supposition that *light moves* in *straight lines*, and try to make the projectile go to the desired object as nearly as possible by the *path* along which the *light comes from the object to the eye.*

Q. Why does a carpenter look along the EDGE of a plank to see if it is STRAIGHT?

A. If the edge be straight and uniform, the light from all points of the edge will come to the eye *regularly* and *uniformly;* if irregularities, however, exist, they will cause the light to be *irregular*, and the eye at once notices the confusion and the point which occasions it.

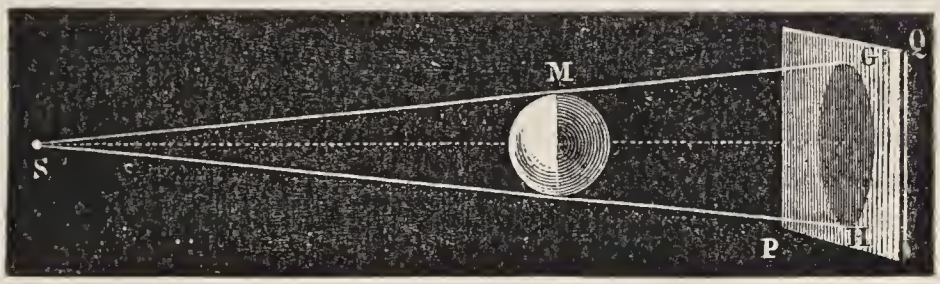
Q. When will the shadow of a body be LESS than the body casting it?

A. When the *luminary is greater* than the body casting the shadow, a cross section of the shadow thrown upon a plane surface will be less than the body; and less, moreover, the farther this surface is from the body, for the shadowed space terminates in a point.

Q. Under what circumstances will the shadowed space be GREATER than the body producing it?

A. When the light-giving surface is *smaller* than the body casting the shadow, the shadow will be larger than the body (*see fig.* 95): thus the shadow of a hand held *near* a candle, and between a candle and the wall, is gigantic.

Fig. 95.



Q. What is meant by the ABERRATION of light?

A. By aberration of light is meant the *difference between the real* and *apparent places* of the stars. As the light is proceeding from them, the earth is moving onwards; consequently they appear to be rather more backward than they really are in the direction of the earth's annual motion.

Q. What is a MIRROR?

A. Any substance *reflecting light.* The term is generally applied to glass covered on the back with quicksilver.

Q. What is a SPECULUM?

A. The term speculum is generally applied only to *metallic mirrors*, made usually of a mixture of tin and copper.

Q. How MANY KINDS of mirrors are there?

A. Three: *plane*, *convex*, and *concave.*

Q. What is a familiar EXAMPLE of a plane mirror?

A. A common *looking-glass.*

Q. What is a CONVEX MIRROR?

A. A convex mirror is a part of a *sphere* or *globe* reflecting from the *outside.*

Q. How does the IMAGE always APPEAR in a convex mirror?

A. Always *smaller* than the object.

Q. What is a CONCAVE MIRROR?

A. The shape of a concave mirror is exactly like that of the convex mirror, the only difference between them being in respect to their *reflecting surfaces.* The reflection of a *concave mirror* takes place from its *inside*, or concave surface, while that of the *convex mirror* is from the *outside*, or convex surface.

Q. How do IMAGES APPEAR in a concave mirror?

A. Concave mirrors *magnify*, or render the image *larger* than the object.

CHAPTER XXX.

REFLECTION OF LIGHT.

Q. When light falls upon a body, in what THREE ways may it dispose of itself?

A. It may be *reflected*, *refracted*, or *absorbed*.

Like radiant heat, it will dispose of itself in one or more of these three different ways.

Q. What is the REFLECTION of LIGHT?

A. When a ray of light strikes a polished surface, it is thrown back, or, as we say, *reflected*.

Q. What are those POLISHED SURFACES which reflect light CALLED?

A. *Mirrors*.

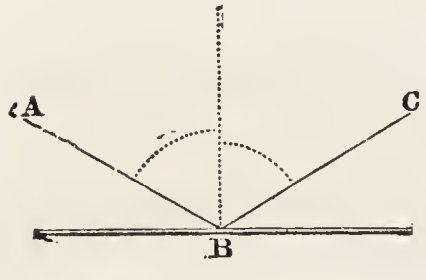
Q. In WHAT WAY are rays of light reflected from a mirror?

A. In the same way that a *stone rebounds* if thrown against a wall.

Q. How is this DESCRIBED?

A. By the *lines of incidence* and *reflection*. The course taken by rays of light towards the mirror is the line of incidence; the course taken by those rays in rebounding from the mirror is the line of reflection.

Fig. 96.



In this diagram, if the line of *incidence* be A B, the line of *reflection* is B C.

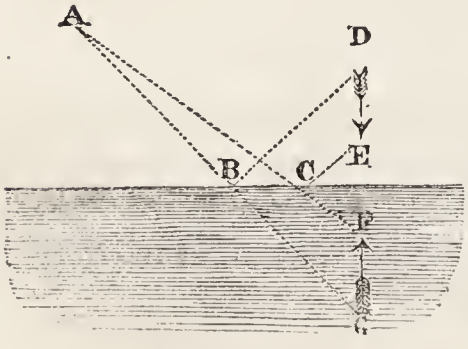
Q. How is it that the DISTANCE of any object from a looking-glass seems as GREAT BEHIND that glass as the real object is BEFORE it?

A. This effect is the result of the principle just stated, the line of reflection being always equal to the line of incidence.

Q. If we look at any object in the water it appears INVERTED, or UPSIDE DOWN: why is this?

A. It is only another illustration of the same principle; the angle of incidence being equal to the angle of reflection.

Fig. 97.



In the accompanying diagram, the feather of the arrow D strikes the water at B, while the reflection of it is seen at G. The barb of the arrow E strikes at C, and is reflected at F. If the spectator be supposed to stand at A, the reflection will have the appearance represented in the diagram.

Q. On a lake of water the MOON seems to make a PATH of light towards the eye of the spectator, while all the REST of the lake seems DARK: why is this?

A. The reason of this appearance is that every little wave, in an extent perhaps of miles, has some part of its rounded surface with

the direction or obliquity which, according to the required relation of the angles of incidence and reflection, fits it to reflect the light to the eye, and hence every wave in that extent sends its momentary gleam, which is succeeded by others.

Q. Why can we NOT SEE into the STREET OR ROAD when CANDLES are LIGHTED ?

A. Because glass is a reflector, and throws the candle-light *back into the room* again; and the pupil of the eye (having become *contracted* by the light of the room) is *too small* to collect rays enough from the dark street to enable us to *see into it.*

Q. Why do we often see the FIRE REFLECTED in the WINDOW ?

A. Because glass is a *good reflector*, and the rays of the fire (striking against the window-glass) *are reflected back into the room again.*

Q. How does LIGHT cause the pupil of the eye to CONTRACT ?

A. The pupil of the eye is a round hole in the midst of a movable muscular curtain or screen, called the *iris.* When too much light falls on the nervous retina at the back of the eye, it *irritates* it; and this *irritation* is conveyed to the muscular rings composing the curtain by small nervous fibres, causing them to contract.

Q. What is the KALEIDOSCOPE ?

A. An *optical instrument*, invented by Sir David Brewster. It consists of a tube, with narrow slips of looking-glass so placed on the inside, that small beads, pieces of coloured glass, and substances of a like kind, are reflected by them in regular and most elegant combinations of form. These combinations may be varied in endless succession, since every time the instrument is moved about or shaken a new figure is produced.

Q. In a long, straight STREET, why do the houses on the opposite sides seem to APPROACH NEARER together as they are more DISTANT ?

A. Because the more *distant the houses* are, the more *acute will be the angle* which any opposite two make with our eye.

Q. Why does the MOON appear LARGER than the STARS ?

A. Because the moon, which is in reality much *smaller* than most of the stars, being *very much nearer to us* than any of them, it has the appearance of being *larger.*

Q. What is the meaning of PERSPECTIVE ?

A. The science of perspective teaches to draw *on a plane surface* true *pictures* of objects as they *appear to the eye* from any distance and in any position.

"Plane surface," a flat or even surface. The word perspective is from the Latin *per* (through), and *specio* (to look).

Q. An object in the SHADE is not so bright and apparent as an object in the sunshine : why is this ?

A. Because objects in the shade are seen by reflected light *reflected;* that is, the light is *twice* reflected; and, as the rays of light

are always absorbed in some measure by every substance on which they fall, therefore some light is lost: 1. Before the *second* reflection is made; and, 2. In the object that *makes* the second reflection.

Parts of the rays are absorbed, and parts are scattered in all directions by irregular reflections; so that rarely more than half are reflected, even from the most polished metals.

Q. Why is it light when the sky is covered with thick clouds?

A. Because the multiplied reflections of the sun in the atmosphere are sufficient to give light upon the earth, even when thick clouds obscure the sun.

Q. If a picture be highly VARNISHED, or covered with a GLASS, it cannot be seen in certain positions: why not?

A. 1. Because the glass or varnish is a *reflector;* and, whenever a strong light is reflected from the glass to the eye of the spectator, the glass or varnish becomes very *luminous*, and the picture remains in comparative *darkness;* and

2. When the spectator is so placed as to catch the rays of light reflected from the glass or varnish, his eye is *dazzled*, and cannot see the more faintly illuminated picture.

Q. What is the use of telescopes?

A. They *gather together* the rays of light, and a greater number are thus brought to the eye.

Fig. 98.

A TELESCOPE.

Q. How can these rays be GATHERED TOGETHER?

A. Rays of light diverge—that is, spread out in all directions—from a luminous object. The number of these diverging rays which will enter the eye is limited by the size of the pupil. But, before they reach the eye, they may be received upon a glass lens of a convex form, which will have the effect of collecting them into a space

less in magnitude than the pupil of the eye. If the eye be placed where the rays are thus collected, all the light will enter the pupil.

Q. Why do TELESCOPES enable us to SEE objects INVISIBLE to the naked eye?

A. Because they gather together more luminous rays from obscure objects than the *eye* can, and form a bright image of them in the tube of the telescope, where they are magnified.

Q. How MANY KINDS of telescopes are there?

A. Two: *reflecting*, and *refracting* or achromatic telescopes.

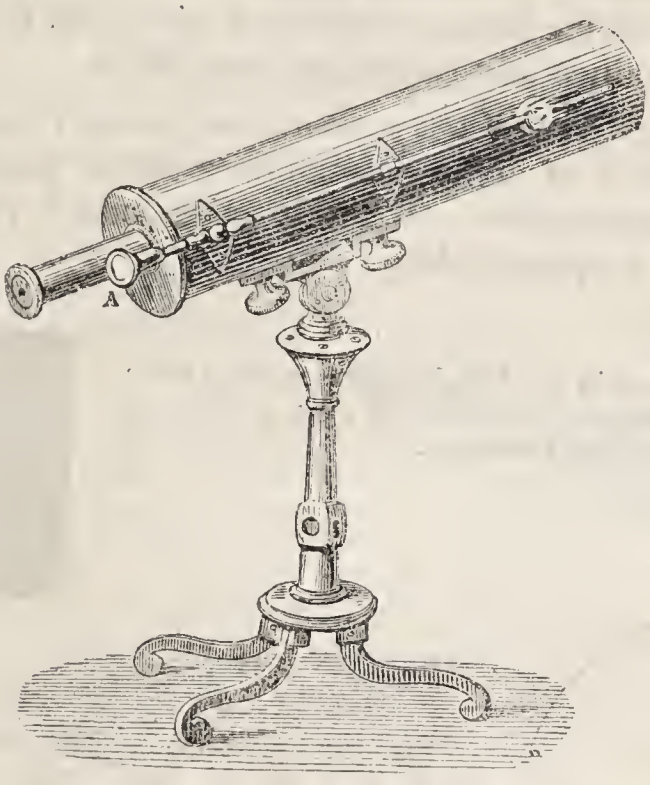
Q. What is a REFLECTING TELESCOPE?

A. One in which we look at the *magnified image* of the object *reflected* from a *mirror* or *speculum*.

Q. What is a REFRACTING telescope?

A. In a refracting telescope the use of a microscope is dispensed with, and we *look directly* at the object through a series of *magnifying lenses*. The common spy-glass and the opera-glass are examples of the refracting telescope.

Fig. 99.

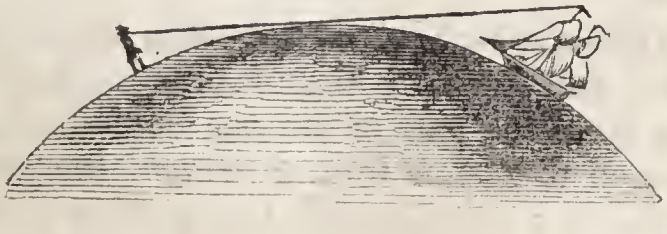


DR. GREGORY'S TELESCOPE, INVENTED 1650.

Q. When a SHIP is approaching the shore, why are the MASTS seen before the HULL?

A. Because the *earth is round*; and the *curve* of the sea *hides the hull* from our eyes after the tall *masts* have become visible.

Fig. 100.



CHAPTER XXXI.

REFRACTION AND ABSORPTION OF LIGHT.

Q. What is meant by the REFRACTION of light?

A. Light traverses a given transparent medium, such as air, water, or glass, in a straight line, provided no reflection occurs, and there is no change of density in the composition of the medium; but when light passes from *one medium into another*, or from one part of the *same medium* into *another* part of a *different density*, it is *bent* from a straight line, or refracted.

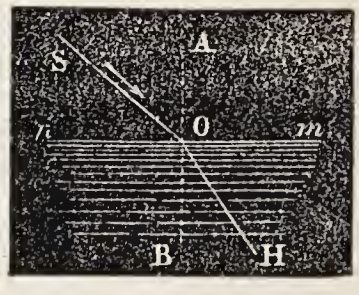
Q. Does AIR possess the property of REFRACTING LIGHT?

A. Yes; the more *dense* the air, the greater is its *refractive* power. Consequently, that portion of the atmosphere at the earth's surface possesses the greatest refractive power; its density gradually diminishing according to its distance from the earth, till it becomes so rare as scarcely to produce any refraction upon light.

Q. How is a ray of light BENT as it passes from one medium to another?

A. When a ray of light passes into a *denser* medium, it is bent *towards* the perpendicular. When it passes into a *rarer* medium, it is bent *from* the perpendicular.

Fig. 101.



Let the *incident* ray, in fig. 101, be represented by S O; the line O H represents the *refracted* ray; A B shows the angles of incidence and refraction.

Fig. 102.

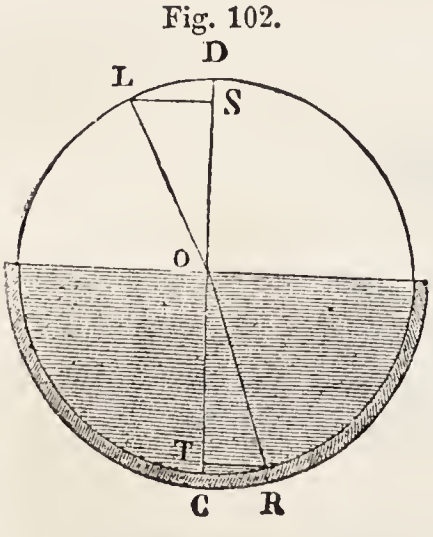


Fig. 102 represents a globe half filled with water. L O is a ray of light, which, entering the denser medium of the water, changes its course to R. The different angles formed are evident. D O L is the angle of incidence; R O C the angle of reflection. The angle is taken from the perpendicular line S T.

Q. Why does the part of an OAR immersed in the water appear BENT OR BROKEN?

A. The water and the air being of different densities, the rays of light proceeding from the part of the oar contained in the water are *refracted*, or caused to *deviate* from a *straight line*, as they pass from the water into the air; consequently that portion of the oar immersed

in the water will appear to be *lifted up*, or to be *bent* in such a manner as to form an angle with the part out of the water.

As all rays of light are refracted more in their passage through water than in their passage through air, they will, at the intersection of the two mediums, tend to cross each other and form an angle.

Q. Upon what does the refracting power of bodies DEPEND ?

A. Chiefly upon their *density*. A mixture of sulphuric acid and water will refract or bend the ray of light more than simple water, and a plate of glass more than either.

Q. What CURIOUS PROPERTY have inflammable bodies in respect to the refraction of light ?

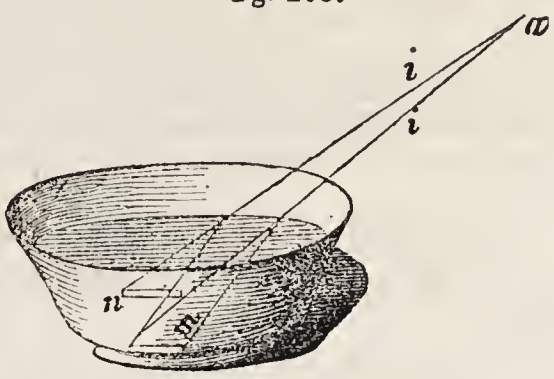
A. All highly *inflammable bodies*, such as oils, hydrogen, the diamond, phosphorus, sulphur, amber, camphor, &c., have a refractive power from *ten to seven times greater* than that of *incombustible* substances of equal density.

Q. What CURIOUS PREDICTION did Sir Isaac Newton make respecting the diamond, from its great refractive power ?

A. Having noticed that the diamond refracted light powerfully, he predicted that it would from this circumstance be found to be *inflammable*. Many years afterwards this *prediction* was *verified*.

Q. What SIMPLE EXPERIMENT illustrates the effect of refraction ?

Fg. 103.



A. Place a silver coin *m* at the bottom of a basin, *fig.* 103. The rays *i i* proceeding to the eye from the silver surface, render the coin visible. The point *a*, the eye, is then moved farther back, so that the edge of the basin obstructs the direct rays, and of course the coin is no longer seen. If an attendant carefully pours water into the basin, so that the object is not moved, it will presently, as the water rises in the basin, become again visible. This arises from the *refraction of the rays* by the water, the image, indeed, appearing at *n* instead of at *m*.

Q. How is this refraction of light ACCOUNTED for and EXPLAINED ?

A. According to the undulatory theory of light, refraction is due to an *alteration* in the *velocity* at which the ray of light travels. According to the corpuscular theory, it is accounted for on the supposition that different substances exert different attractive influences on bodies coming within their influence; a highly attractive medium is supposed to exert a strong attractive force, while a weaker force is exerted by those in which the attractive power is less.

Q. What remarkable OPTICAL EFFECT is produced by REFRACTION ?

A. The *mirage*.

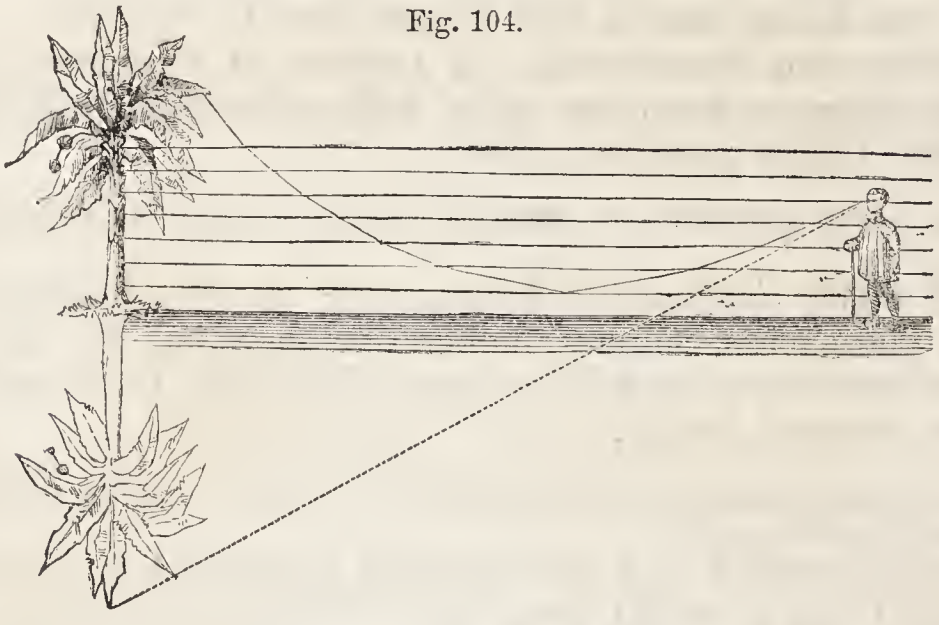
Q. What is the MIRAGE ?

A. An *optical illusion*, by which we appear to see distant objects inverted.

Q. How is this effect produced ?

A. By the *unequal density* of the air.

Fig. 104.



OPTICAL EFFECT OF THE MIRAGE.

The phenomena of the mirage is especially observable on the hot sandy plains of the desert. There the images of trees and water are often seen by travellers when neither are at all near. It arises from the unequal medium through which the light travels. Thus, as seen in fig. 104, the angle of incidence increases from one stratum to that which follows, and finishes by attaining an angle of limit, beyond which reflection succeeds to refraction. The ray is then elevated, undergoes another series of refractions, till it reaches the eye of the spectator, who observes an inverted image, as if it were reflected in water.

Q. Is a ray of white light SIMPLE or COMPOUND ?

A. Every ray of white light is *compounded* of other rays of *coloured light.*

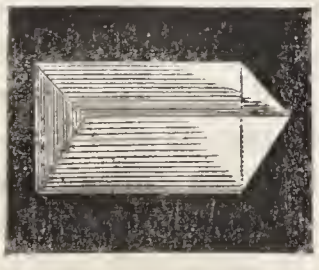
Q. How is it known that a ray of light consists of several different colours ?

A. A ray of light cast upon a prism, is divided into three colours, Red, Blue, and Yellow. These mixing, produce Orange, Green, Indigo, and Violet.

Q. What is a PRISM ?

A. A *solid piece of glass*, triangular in form. (*See fig.* 105.)

Fig. 105.



A PRISM.

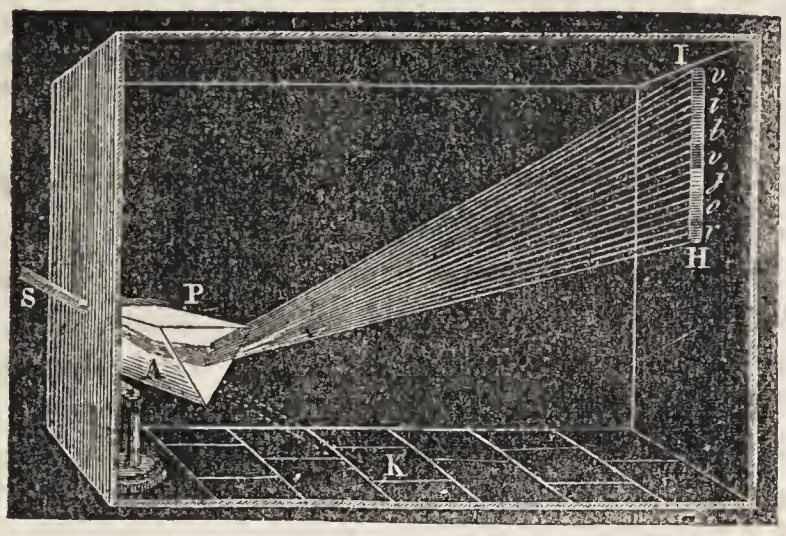
Q. How does a PRISM separate a ray of light into SEVEN COLOURS ?

A. It is attributable to the fact of all these colours having *different refractive susceptibilities.* Red *least*, and blue the *most;* therefore, the *blue* ray will be bent to the *top* of the prism, and the *red* will remain at the *bottom.*

The separation of a ray of solar light into different colours, by refraction, may be more accurately displayed by admitting a ray through an aperture in a window-shutter into a darkened chamber, and causing it to fall on a diaphanous prism A P, as represented in the following figure. A ray S thus entering, and suffered to pass unobstructed, would

form on a plane surface a circular disk of white light ; but the prism being so placed that the ray may enter and quit it at equal angles, it will be refracted in such a manner as to form on a screen I, properly placed, an oblong image, called the solar spectrum, and divided horizontally into seven coloured spaces, or bands, of unequal extent, succeeding each other in the order represented : red, orange, yellow, green, blue, indigo, violet.

Fig. 106



Q. Are the coloured rays, once separated and refracted by the prism, capable of being SEPARATED and REFRACTED again ?

A. They are *not*, and are hence designated as *primary colours.*

Q. If the seven different colours as separated by the prism be again collected together, WHAT will they form ?

A. *White light.*

Q. What TERM has been applied to the seven different colours separated by the prism from a ray of light ?

A. The *solar spectrum.*

Q. To what is the great BRILLIANCY of the diamond, and other precious stones, DUE ?

A. To their power of *refracting light ;* they are also artificially cut in such a manner as to form a series of *prisms*, which separate the rays of light falling on them into their *component coloured rays.*

Q. Why do BLUE and YELLOW powders, when mixed, form a GREEN powder ?

A. Because of the mere *effect* arising in the *eye* from the intimate mixture of the yellow and blue light, separately and independently reflected from the minute particles of each ; the *proof* of this is had by examining the mixture with a *microscope*, when the yellow and blue grains will be seen *separately*, and *quite unaltered.*

Q. Why cannot a SIMILAR SEPARATION be detected in liquid green, produced by agitating blue and yellow liquids together ?

A. Because of the *excessive minuteness* of the parts, and their *perfect intermixture ;* from the mixture of two powders, extreme patience would enable any one, by picking out with a magnifier, grain after grain, to separate the ingredients ; but when liquids are mixed, no mechanical separation is practicable ; the particles are so minute as to elude all search.

Q. What is a RAINBOW ?

A. The rainbow is a *semicircular band* or *arc*, composed of the

different colours, generally exhibited upon the clouds during the occurrence of rain in sunshine.

If we take a glass globe filled with water, and suspend it at a certain height in the solar rays above the eye, a spectator standing with his back to the sun will see the refraction and reflection of red light; if then the globe be lowered slowly, the observer retaining his position, the red light will be replaced by orange, and this in its turn by yellow, and so on, the globe at different heights presenting to the eye the seven primitive colours in succession. If now, in the place of the globe occupying different positions, we substitute drops of water, we have a ready explanation of the phenomena of the rainbow.

Q. What is the CAUSE of the rainbow?

A. The rainbow is produced by the *refraction* and *reflection* of the solar rays in the *drops* of *falling rain.*

Q. What are the CONDITIONS NECESSARY in order that we may see a rainbow?

A. The rainbow can be seen only when it *rains*, and in that point of the heavens which is *opposite* to the *sun.* It is necessary also that the sun should not have too great an *altitude above the horizon.* Hence, within a certain interval each day, no visible rainbows can be formed, on account of the sun's high altitude above the horizon.

If the altitude of the sun exceeds forty-two degrees, no complete bows can be formed, the summits being depressed below the horizon.

Q. How do we KNOW that the rainbow results from the decomposition of the solar rays by drops of water?

A. Because, in the case of *cascades* and *waterfalls*, the *spray* and the drops of moisture dispersed over the grass and the spiders'-webs produce the *same phenomena.*

Q. What is the cause of morning and evening TWILIGHT?

A. When the sun is below the horizon, the rays which strike upon the atmosphere or clouds are *bent down towards the earth*, and produce a little light called twilight.

Q. Sometimes SHIPS are DISTINCTLY SEEN by an observer on shore before they are actually above the horizon: explain this.

A. This is owing to the *refracting* power of the atmosphere at the time. The different strata of air being of *unequal density*, the rays of light from the ship to the eye of the observer are *bent* in a *curve;* so that the vessel is visible before it is really above the horizon.

It is owing to this refracting power of the atmosphere that the sun appears to us before he rises, and we see him after he has actually set.

Q. Why does MOTHER-OF-PEARL show so many colours?

A. Mother-of-pearl consists of a number of very thin half-transparent layers of unequal thickness, overlapping each other like the scales of a fish.

Where these layers terminate are very small grooves or streaks running in all directions, which act like prisms.

It is these *streakings* or grooves which cause the various and changing colours of mother-of-pearl.

The same thing may very easily be imitated, and is frequently done in what are called "iris ornaments," first invented by John Barton, Esq., of the Royal Mint. These iris ornaments are made of steel, and have about thirty thousand grooves per inch; they are used in court dresses, for buttons, sword-handles, &c., and are very brilliant indeed.

Mother-of-pearl may also be imitated, by taking impressions of it in wax, balsam of tolu, isinglass, or gum; these impressions will exhibit all the shades and colours of mother-of-pearl, merely because the impression will be streaked or grooved in a similar way.

Q. How is it that the stars appear to TWINKLE?

A. Because the inequalities and undulations in the atmosphere occasion *unequal refractions of light*, which produce the *twinkling* appearance or irregular light of the stars.

Q. What is supposed to be the CAUSE of the refraction of light?

A. According to the undulatory theory of light, refraction is due to an *alteration in the velocity* at which the ray of light *travels*. According to the corpuscular theory, it is accounted for on the supposition that *different substances* exert *different attractive* influences on bodies coming within their influence.

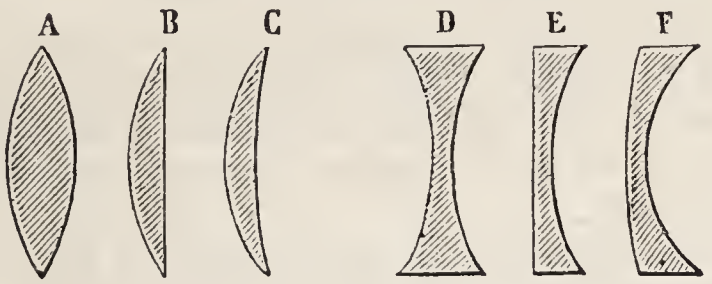
Q. What is a LENS?

A. A piece of *transparent glass*, bounded on both sides by polished spherical surfaces, or on the one side by a spherical, and on the other by a plane surface. Rays of light passing through it are made to change their direction, and to *magnify* or *diminish* the appearance of objects at a certain distance.

Q. How many VARIETIES of lenses are generally recognised?

A. Two: *convex* and *concave*.

Fig. 107.



Among convex lenses are the double convex, A (*fig.* 107), to which the appellation *lens* was originally applied from its resemblance to a lentil-seed (*lens* in Latin), being bounded by two convex spherical surfaces whose centres are on opposite sides of the lens; the plano-convex, B, having one side bounded by a plane surface, and the other by a convex surface; and the meniscus or concavo-convex, C, bounded on one side by a concave, and on the other by a convex surface: the former being a portion of a larger circle than the latter, and therefore the surfaces meet when produced.

There are also three principal varieties of concave glasses; as the double concave, D, bounded by two concave surfaces, forming portions of spheres whose centres are on opposite sides of the lens; the plano-concave, E, bounded on one side by a plane, and on the other by a concave surface; and convexo-concave F, bounded by a convex surface on one side, and by a concave one on the other; but these surfaces, when produced, do not meet.

Q. What is a FOCUS of light?

A. When rays of light continually *approach* each other, as in moving to a point, they are said to *converge*, and the point at which the converging rays *meet* is called the *focus*.

Q. What sort of a lens is a common BURNING-GLASS?

A. A *double convex* lens.

Q. What are HALOES ?

A. *Coloured rays* seen round luminous bodies, as the moon or sun.

Q. Under what CIRCUMSTANCES are they produced ?

A. When the atmosphere contains *moisture* in such a condition that it *refracts* and *decomposes* the rays of light proceeding from the luminous body.

Q. What are TRANSPARENT bodies ?

A. Those which do *not interrupt* the passage of light, or which admit of other bodies being seen through them.

Q. When is a body SEMI-TRANSPARENT ?

A. When it allows other bodies to be seen through it, but only *imperfectly* and *obscurely*.

Q. When is a body OPAQUE ?

A. When it entirely *prevents* the passage of light.

Q. Why are some things TRANSPARENT ?

A. We cannot clearly explain what there is in the constitution of one mass of matter, as compared with another, which fits the one to transmit light, and the other to obstruct it; but the *arrangement of the particles* has undoubtedly much influence.

Q. Upon what QUALITY does the transparency or opacity of substances especially DEPEND ?

A. Upon their *relative thickness* or *thinness*. Thus gold can be beaten so thin as to transmit a soft green light.

Q. HORN is partially transparent : why are not horn SHAVINGS the same ?

A. Because the surface of the shaving has been *torn* and rendered *rough ;* and the rays of light are too much *reflected* and *refracted* by the rough surface to be transmitted through the shaving so as to produce transparency.

If the parts of any substance are not pretty uniform, the rays of light are refracted and absorbed so frequently, that no part of them can emerge on the opposite side.

Q. Is there any body PERFECTLY TRANSPARENT ?

A. No; some light is evidently *lost* in passing even through space, and still more in traversing our atmosphere.

Q. How much of the sun's light is supposed to be INTERCEPTED by the atmosphere ?

A. It has been calculated that the atmosphere, when the rays of the sun pass perpendicularly through it, intercepts from one-fifth to one-fourth of their light; but when the sun is near the horizon, and the mass of air through which the solar rays pass is consequently vastly increased in thickness, only one *two hundred and twelfth* part of their light can reach the surface of the earth.

Q. Why is charcoal BLACK ?

A. Because it *absorbs* all the light which falls upon it, and *reflects* none.

Q. What BECOMES of the light which is absorbed ?

A. This question cannot be satisfactorily answered. In all pro-

bability it is *permanently retained* within the substance of the absorbing body.

Q. How THICK must our atmosphere be to absorb all the light emanating from the sun?

A. If our atmosphere in its state of greatest density could be extended rather more than *seven hundred* miles from the earth's surface, instead of *forty* or *fifty*, as it is at present, the sun's rays could *not penetrate through* it, and our globe would roll on in darkness.

Q. To what DEPTH is light supposed to penetrate the ocean?

A. It is calculated that sea-water loses all its transparency at the depth of *seven hundred and thirty* feet; but a dim twilight must prevail much deeper in the ocean.

Q. If the objects of the material world had been illuminated with white light, all the particles of which possessed the same degree of refrangibility, and were equally acted upon by the bodies on which they fall, what would have been the APPEARANCE of nature?

A. All nature would have shown with a *leaden hue*, and the combinations of external objects, and all the features of the human countenance, would have exhibited no other variety than that which they possess in a *pencil sketch* or *India-ink drawing*.

CHAPTER XXXII.

COLOUR.

Q. What is the efficient CAUSE of colours?

A. The *action of light*.

Q. How is this PROVED?

A. In the dark, bodies have no colour, and in the light their colours may be altered by subjecting to certain modifications the light by which they are rendered visible. Thus everything in a *red light* will appear *red*.

Q. Why is it that we find it difficult to distinguish colours by CANDLE-LIGHT?

A. Because we have *modified* the light upon which the full effect of the colour depends.

Q. What, then, is the true DEFINITION of colour?

A. The colour of a substance is the *effect of light* on a surface adapted to reflect its particular colour.

Q. How is it that ALL objects do not reflect the SAME colour?

A. On account of their *different substances* and *chemical properties*.

Q. Why are some things RED?

A. Because they *absorb* all the yellow and blue rays, and reflect only the red.

Q. Why are some things BLACK?

A. Because they *absorb all* the rays of light, and reflect *none*.

Q. Is BLACK a colour?

A. It is not; it is the *absence* of colour.

Q. Why are some things WHITE?

A. Because they *absorb none* of the rays of light, but reflect them all.

Q. Why are clouds, snow, sugar, and salt WHITE?

A. Because they *reflect back* unchanged the *white light* which strikes upon them.

Q. Why are the LEAVES of plants GREEN?

A. Because a peculiar chemical principle, called chlorophyl, is formed within their *cells*, which has the property of absorbing the *red* rays, and of reflecting the blue and yellow, which mixture produces *green*.

Q. Why do all things appear BLACK in the DARK?

A. In the dark there is no colour, because there is no light to be absorbed or reflected, and therefore none to be decomposed.

Of course, in certain degrees of darkness, all objects are actually *invisible*. The question refers to that peculiar degree of darkness when the *forms* of objects may be seen, but not their *hues*.

Q. Why does the sky appear BLUE?

A. Because the atmosphere *absorbs* the *red* and *yellow* rays, and transmits the *blue*.

Q. Why are some PLANTS WHITE which are kept in the DARK?

A. Because chlorophyl can be formed only by the agency of the sun's rays; and it is this peculiar principle which gives the green tinge to healthy leaves and plants.

Some plants are a yellowish green from the same cause.

Q. Why does the SUN most generally FADE artificial COLOURS?

A. Generally the loss of colour arises from the oxidation of the substances used in dyeing; as tarnish and rust are an oxidation of metals. Sometimes, however, the ingredients of the dye are otherwise decomposed by the sun; and the colour (which is due to a *combination* of ingredients) undergoes a change as soon as the sun deranges or destroys that combination.

Q. What is meant by the term ACCIDENTAL COLOUR?

A. The *accidental colour* is the colour which would be required to be added in order to make up *white* light: thus, the accidental colour of red is bluish green; of orange is blue; of yellow is indigo; of green is reddish violet; of blue is orange red; of indigo is orange yellow; of violet is yellow green; of black is white; of white is black.

Q. What surfaces REFLECT LIGHT best

A. *Smooth* and *polished* surfaces are the best reflectors of light.

Q. Glass is a smooth polished surface: is it a good reflector of light?

A. Glass is *transparent*, and therefore transmits light; but if one

of its surfaces be covered with quicksilver, the light cannot pass through it, and is consequently *reflected.*

Q. Why do SANDY PLAINS DAZZLE from sunshine?

A. Because each grain of sand *reflects the rays of the sun* like a mirror.

Q. How is the origin and production of colour ACCOUNTED FOR, according to the corpuscular theory?

A. According to this theory, white light is an *assemblage of atoms* of various colours, which may be separated from each other by the action of a prism; and bodies, when exposed to the rays of the sun, display any given colour, because they are so constituted as to absorb all the atoms except those of the rays of their own peculiar colour; thus perfectly white substances absorb none of the atoms, but reflect the white or compound light unaltered; black substances absorb all the rays, and therefore yield no colour; and red, yellow, and blue substances respectively reflect those rays alone by which they are distinguished.

Q. How is the production of colour accounted for, according to the UNDULATORY theory?

A. The undulatory theory supposes that every simple colour depends on a *certain number* of *vibrations*, which are performed in a *certain time.* If, therefore, the *rate* at which a ray undulates is *altered*, a different sensation is produced upon the optic nerve.

Q. What analogy is there between the seven COLOURS and the seven NOTES in music?

A. The analogy between sound and light, according to the undulatory theory, is *perfect*, even in its *minutest* circumstances. When a certain number of vibrations of a musical chord are caused in a given time, we produce a required sound; as the vibrations of the chord vary from a quick to a slow rate, we produce sounds *sharp* or *grave.* So with light. As the supposed ether varies the rate of its undulations, we have colours *bright* or *dull.*

Q. How MANY TIMES must a ray of light VIBRATE to produce red light?

A. *Thirty-seven thousand six hundred and forty* undulations in an inch, and *four hundred and fifty-five billions* in a second.

Q. How MANY VIBRATIONS are required to produce YELLOW and BLUE light?

A. Yellow light requires *forty-four thousand* in an inch, and *five hundred and fifty-five billions* in a second; while the effect of blue results from *fifty-one thousand one hundred and ten* undulations within an inch, and *six hundred and twenty-two billions* in a second of time.

Q. How are these facts KNOWN and PROVED?

A. Newton proved, by a series of beautiful and satisfactory experiments, the number of vibrations of different coloured rays within the space of an inch. If now, from a star of a red colour, there proceeds a continuous line of waves, these waves will enter the *pupil* of the *eye*, and *strike* upon the *retina.* For each wave that thus strikes upon the retina, there will be a separate *pulsation* of the *membrane.* Its *rate* of pulsation, or the *number* of vibrations it

makes per second, will therefore be known if we can ascertain how many luminous waves enter the eye per second.

Q. How can this fact be ASCERTAINED?

A. Light moves at the rate of about 200,000 miles per second. A length of ray amounting to 200,000 miles must therefore enter the eye each second; the number of times, therefore, that the retina will vibrate per second will be the same as the number of luminous rays contained in a ray 200,000 miles long.

In two hundred thousand miles there are in round numbers a thousand millions of feet, and therefore twelve thousand millions of inches. In each of these inches there are forty thousand waves of red light. In the whole length of the ray, therefore, there are four hundred and eighty millions of millions of waves. Now, as this ray enters the eye in one second, the retina must pulsate once for each of these waves; and thus we arrive at the astounding conclusion that where we behold a red object, the membrane of the eye trembles at the rate of FOUR HUNDRED AND EIGHTY MILLIONS OF MILLIONS of times between every two ticks of the common clock.—LARDNER.

Q. What remarkable correspondence is there between the GEOGRAPHICAL POSITION of a region and the COLOURS of its plants and animals?

A. In the *tropics*, where the sun shines *longest* and *brightest*, the *darkest green* prevails over the leaves of plants, the flowers and fruits are coloured *brightly*, and the plumage of the birds is of the *richest* description.

Q. What is the natural coloration exhibited in TEMPERATE climates?

A. In temperate climates everything is of a more *subdued variety;* the flowers are *less bright;* the prevailing tint of the birds is *brown;* and the dresses of the inhabitants are sombre.

Q. How is this correspondence further exemplified in the ARCTIC and ANTARCTIC regions?

A. Here there is *little colour* in natural objects; the few flowers are *white* or *yellow;* and the animals are almost uniformly *black* or *white.*

Q. In what part of the ocean do we find the BRIGHTEST shells and sea-weeds?

A. Near the *shore*, in shallow water, where the influence of *light* is greatest.

Q. What fishes are distinguished for the BRILLIANCY of their colours?

A. Those that *swim* near the *surface;* whereas those which live at greater depths are gray, brown, and black.

Q. What is the appearance of the sea-weeds and animals that live at great DEPTHS of the ocean?

A. They are *nearly colourless.*

Q. Why is grass growing under a COVERING of a white or yellowish white colour?

A. Because it is secluded from the *light*, whose presence and action is necessary for the production of the material which imparts to it its green colour.

Q. Of the various rays composing solar light, which are the MOST VISIBLE to the human eye?

A. The *yellow.*

Q. Which have the greatest HEATING effect?

A. The faint *red* rays.

Q. Why does a dress composed of cloths of DIFFERENT COLOURS look well much LONGER, although worn, than one of only a SINGLE COLOUR, the character of the cloth in both instances being identical?

A. It is owing to the effect of *contrast* between the colours. If a dress is composed of cloths of two colours, the one *complementary* to the other, as red and green, orange and blue, yellow and violet, they will mutually heighten the effect of each, and make each portion appear to the best advantage.

Q. Why will STAINS be less visible on a dress of DIFFERENT colours, than on one composed of only a SINGLE colour?

A. Because there exists in general a greater *contrast* among the various parts of the first-named dress, than between the stain and the adjacent part, and this difference renders the stain less apparent to the eye.

Q. Why can a coat, waistcoat, and trowsers of the SAME COLOUR be worn with advantage together only when they are NEW?

A. Because as soon as one of them loses its freshness from having been worn longer than the others, the difference will *increase* by *contrast.*

Q. Give an ILLUSTRATION?

A. A pair of new black trowsers, worn with a vest of the same colour, which is old and rusty, will make the tinge of the latter appear more conspicuous; and, at the same time, the black of the trowsers will appear more brilliant. White and other light-coloured trowsers would produce a contrary effect.

Q. What is the GENERAL LAW upon which the harmony of colours DEPENDS?

A. Every colour when placed beside another colour is *changed*, appearing different from what it really is; and it moreover equally modifies the colour with which it is in proximity.

Q. What EFFECT has rose-red upon a rosy complexion?

A. It causes it to *lose* some of its *freshness.*

Q. For fair complexions, deficient in rose, which colour is MOST FAVOURABLE?

A. A *pale blue.*

Q. What EFFECT has black drapery upon the colour of the skin?

A. It makes it appear *whiter.*

Q. What RULE should be observed in the grouping of flowers and the preparation of bouquets?

A. We must separate pink flowers from those that are either scarlet or crimson; orange from orange-yellow flowers; yellow flowers from greenish-yellow flowers; blue from violet-blue, red from orange, pink from violet; blue flowers from violet flowers.

Q. What is the OPTICAL EFFECT of dark colours and black upon the SIZE of the figure?

A. It causes it to appear *smaller;* therefore these colours are most suitable for stout persons.

Q. What EFFECT does white and light-coloured dresses have upon the SIZE of the figure?

A. They cause it to appear *larger.*

Q. What EFFECT is produced by a large patterned dress ?

A. It makes the figure look *shorter.*

Q. What is the EFFECT of narrow longitudinal stripes in dress ?

A. They add to the apparent *height* of the figure.

Q. What is the EFFECT of horizontal stripes ?

A. The effect of horizontal stripes is opposed to that of longitudinal, and under every condition they are *ungraceful.*

Q. What colours are most CONSPICUOUS in battle ?

A. It has been found, by numerous observations, that *red* is the most fatal colour, and the least fatal is a *light gray.*

Q. What CURIOUS PROVISION for the protection of animals does nature appear to make ?

A. She appears to have adapted the *colour* of the creature to its *haunts* in such a way as tends to *preserve* it from *injury.* Caterpillars and insects which feed on leaves are generally of the colour of the leaves. As long as they remain still, it is almost impossible to distinguish the grasshopper from the herbage on which it rests.

Q. What CURIOUS CHANGE is noticed in the COLOUR of animals inhabiting the Arctic regions ?

A. During the snows of winter, foxes, hares, and some varieties of birds are *white ;* when the ground is free from snow in summer, they are of a *brown* colour.

Q. How are FROGS found to escape observation and notice ?

A. By *varying their colour* according to the mud or sand that forms the bottom of the ponds or streams which they frequent ; and the tree-frog takes its specific name (*Hyla vividis*) from the colour of the leaves of the trees it inhabits.

CHAPTER XXXIII.

THE ORGANS OF VISION.

Q. Of what PARTS does the eye consist ?

A. The eye is of globular form, and is composed of three coats or membranes, called the *sclerotic*, the *choroid*, and the *retina ;* and three humours, denominated the *aqueous*, the *crystalline*, and the *vitreous.*

Q. What is meant by the "RETINA of the EYE ?"

A. The *network* which lines the *back of the eye ;* it is composed of an expansion of the optic nerve.

Q. What is that portion of the eye called which in some persons is BLUE, in others GRAY or HAZEL ?

A. It is called the *iris.*

Q. In the centre of the iris is a circular BLACK OPENING : what is this called ?

A. It is called the *pupil.* But this spot is not a black substance, but an *aperture*, which appears black only because the chamber

within it is dark. It is, properly speaking, the *window* of the eye, through which light is admitted, which strikes on the *retina*.

Q. Does light admitted through the pupil to the RETINA produce VISION?

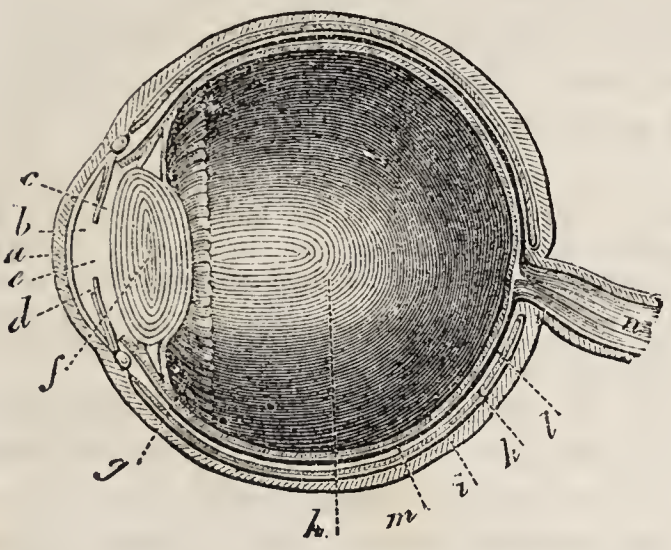
A. Yes; provided the light enter in sufficient quantity.

Q. What is meant by the "CORNEA of the EYE?"

A. All the *outside* of the visible part of the *eyeball*.

The construction of the human eye may be seen from the accompanying diagram, which represents a transverse section of the eye. The eye itself, it will be seen, is shaped like a globe. It is composed of the following substances:—

Fig. 108.



The CORNEA (*a*), a transparent MEMBRANE, or COAT, in front of the ball of the eye.

The SCLEROTIC (*i*) a membrane which, with the CORNEA, covers all the constituent parts of the eye.

The IRIS (*d*), the delicate muscle which gives colour to the eye. This IRIS is pierced by an opening called the PUPIL. By the pupil the rays of light penetrate to the eye.

The AQUEOUS HUMOUR (*e*) occupies the spaces, chambers as they are called, marked *b* and *e*.

The CRYSTALLINE LENS is placed behind the IRIS (*g*).

The VITREOUS HUMOUR, which resembles in appearance the white of an egg, occupies the part of the eyeball behind the crystalline, marked *h*.

The RETINA (*m*) receives the impression of the light, and transmits it to the brain by a NERVE, marked *n*.

The CHLOROID MEMBRANE, between the RETINA and the SCLEROTIC, is marked *k*. It absorbs all the rays of light which are not required for vision.

Q. What is the SCLEROTIC?

A. That *water*, which, with the cornea, *covers* all those muscles which form the human eye.

Q. What is the IRIS?

A. It is a very delicate muscle, which gives colour to the eye: blue, brown, gray, or black.

Q. What is meant by the HUMOURS of the eye?

A. That *matter* which fills up the cavity or chamber of the eye, namely, the *aqueous* or watery, the *vitreous* or glassy, and the *crystalline*.

Q. What is the RETINA?

A. The *innermost coat of the eye*, which, receiving the impression of light, transmits it to the brain.

Fig. 109.

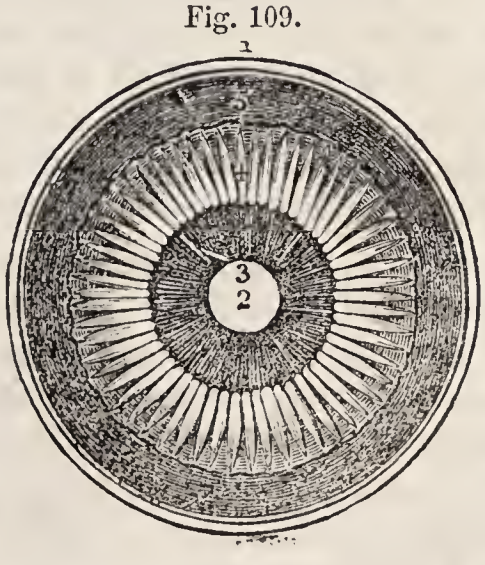


Fig. 108 is a section of the human eye, seen from within. In this engraving we have represented, 1, the coat of the eye; 2, the pupil; 3, the iris; 4, the ciliary process; 5, the border of the retina.

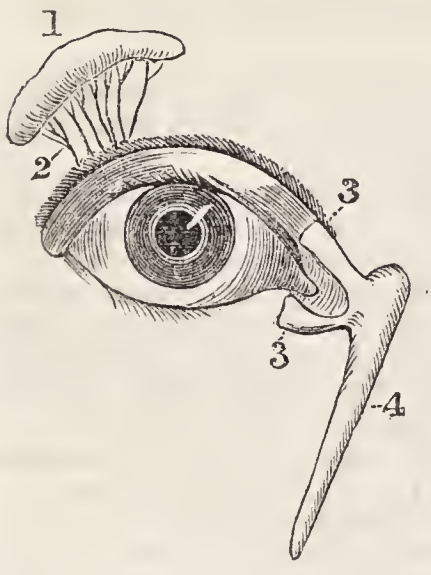
Q. What is the USE of the EYEBROWS?

A. The eyebrows *defend* the eyes from *too strong* a light, and serve to *turn away* substances which might otherwise fall into the eye.

Q. What is the USE of the EYELASHES?

A. The eyelashes *guard* the eye from *danger*, and *protect* it from *dust* or *insects* floating or flying in the atmosphere.

Fig. 110.



Q. What is the USE of the EYELID?

A. The eyelids protect the eye from *too bright rays of light*, and also from dust; they also distribute over the eye a watery fluid, produced in the tear-gland: this watery fluid flows to the eye by several small ducts.

In the cut (fig. 109) are represented, 1, the TEAR gland, or, as it is called, lachrymal gland; 2, the ducts, passing from the gland to the eye; 3, ducts at the corners of the eyes; 4, duct opening into the nose.

Q. What is the RELATIVE SPHERICITY of the eyes of land and aquatic animals?

A. In man, and other land animals, the eyeball is a mass *nearly spherical*, but somewhat flattened in front. Those animals that dwell in the water have eyes *very much flattened*, the eyeball in most fishes forming but half a sphere, and in the ray species it is but one quarter of the thickness of a sphere.

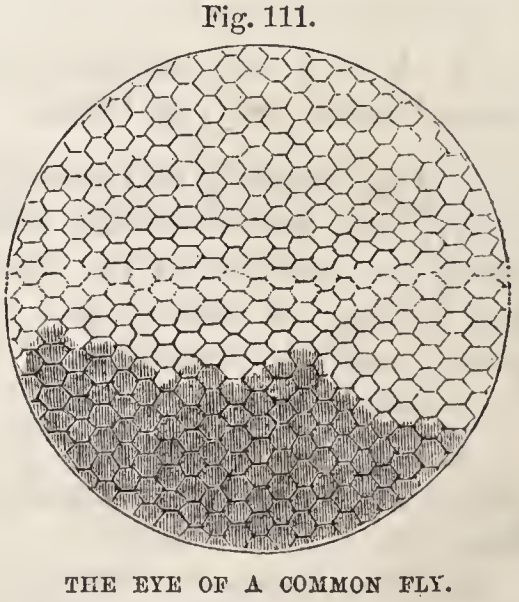
Q. What PECULIARITY is found in the eyes of birds that soar to great heights?

A. In those birds that soar to the higher regions of the atmosphere, the *anterior* part of the eye is sometimes *flat*, and sometimes in the figure of a *truncated cone;* the upper part forming a short cylinder, surmounted by a very convex eminence.

Q. What peculiar ARRANGEMENT exists in the eyes of flies, and some other insects?

A. They have eyes often *very large* in proportion to the bulk of the insect, and composed of a *multitude of small facets*, or *plano-convex lenses*, united into a hemispherical form, with their axes directed to a common focus.

Fig. 111.



THE EYE OF A COMMON FLY.

Q. When we say we SEE an object, what do we in fact DO?

A. The mind is only taking cognisance of the *picture* or *impression* made on the retina.

Q. Why is it that when we PRESS SLIGHTLY upon the ball of either eye, while viewing an object, we see double?

A. Because the *pressure* of the *finger* prevents the ball of one eye

from following the motion of the other, and the axis of vision in each eye being different, we see two images.

Q. Do persons who SQUINT see DOUBLE ?

A. They *do;* but practice gives them power of *attending* to the sensation of only *one eye at a time.*

Q. Why do persons who are short-sighted in youth gradually have this failing CORRECTED as they grow old ?

A. They are short-sighted because the cornea of the eye is *too globular;* but as age advances the fluids are not secreted as before, the eye becomes *flattened*, and natural sight is *again restored.*

Q. If the mind, in seeing an object, sees in reality only a picture painted on the back of the retina, how is it enabled to JUDGE of MAGNITUDES, DISTANCES, &c., the picture being on a comparatively flat surface ?

A. It is only by *experience.* "I see men as trees walking," said the man born blind, when restored to sight.

Q. Would a person whose eyes, although perfect, had been covered up from infancy to maturity, be able TO SEE ?—that is, comprehend any scene or prospect on which he first opened his eyes ?

A. He would *see the objects*, but could *no more understand them* than a child understands the printed page on which it looks, although every word is clear and distinct.

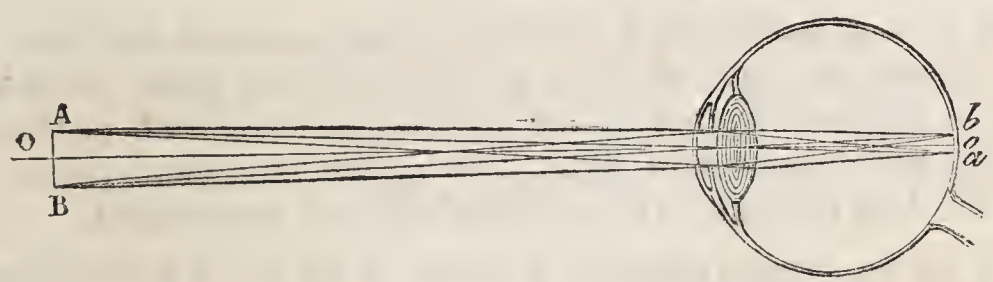
Q. Are the images formed on the retina of the eye ERECT or INVERTED ?

A. Always *inverted.*

Q. Why, then, do we not see objects always UPSIDE DOWN ?

A. It is difficult to satisfactorily answer this question. It is usually said, that although the images formed in the eye are inverted, they are conceived to be erect from the circumstance that everything has always been viewed *under the same conditions.*

Fig. 112.



Various theories have been entertained respecting the reversing of images in the eye. It is the opinion of some that we perceive the real position of objects in the direction of the rays of light which they drive forth, and that as these lines cross each other in the crystalline lens of the eye, we perceive the points A and B in the direction *a* and *b* respectively, whence the object appears upright.

Q. Do we see the same lines and surfaces of an object ALIKE with EACH EYE?

A. We do *not;* and we may convince ourselves that we do not, by placing two *candles*, for example, in such a *position*, that when they are looked at with the *right* eye, one is made to cover the other; if now we close the right eye and look at them with the left,

the most remote candle will be no longer screened by the front one, but will be seen about an inch to the left of it.

Q. What is a STEREOSCOPE ?

A. The stereoscope is an instrument invented by Professor Wheatstone, consisting of *two mirrors*, the backs of which are *inclined* to each other at an angle of 90°.

It will be obvious that if two pictures of the same object are placed at a little distance in front of these mirrors, we shall have two reflected images. If, however, we bring the nose close to the edge at which the mirrors are united, and thus look with an eye into either glass, the two will be resolved into one ; and the resulting image, instead of appearing as a plane surface, appears as a solid, possessing length, breadth, and thickness. The result is very successfully obtained, if the precaution be taken of preparing the drawings so that they represent the object as seen by either eye.

Q. What is the disease called CATARACT ?

A. Cataract is the loss of *transparency* in the *crystalline humour*.

CHAPTER XXXIV.

DECEPTIONS OF VISION.

Q. Why cannot we COUNT the posts of a fence when we are riding rapidly in a railroad train ?

A. Every impression, according to the intensity of its effects, *remains* for a certain length of time on the *retina*, and a *measurable period* is necessary to produce the *impression*. The light from each post falls upon the eye in such rapid succession, that the different images become confused and blended, and we do not obtain a distinct vision of the particular parts.

Q. Why are MORE STARS visible from the top of a HIGH MOUNTAIN than from a PLAIN ?

A. Because the rays of light proceeding from them have to pass through a *thinner stratum* of air in the one case than in the other. Air being an absorbent of light, the higher we ascend in the atmosphere, the less the light will be absorbed and diminished.

Q. How can the apparent magnitude of the sun, at the time of his rising, and again at noonday, be measured ?

A. This may be accomplished by extending two threads of fine silk, fastened in a frame, parallel to each other. The frame should be placed in such a position, and at such a distance from the eye, that when presented to the sun or moon in the horizon, the threads will exactly touch its upper and lower limb, or, in other words, be just sufficiently separated to admit of the disc of the sun or moon to appear between them, and touch. Now, if the sun or moon be viewed in the same manner at noonday, it will be found that the threads are just far enough apart to admit of the disc between them,

showing that the apparent increased magnitude at rising and setting is an optical deception, or rather an error in judgment.

Q. Is this illusion an optical one, or a mental illusion ?

A. A mental one, since the organs of vision do not present to us a larger image of the moon or sun in the horizon than in the zenith.

Q. What do we MEAN by the HORIZON ?

A. The circle or line where the earth and sky *appear to meet.*

Q. What do we mean by the ZENITH ?

A. The point or part of the heavens *immediately overhead.*

Q. Is the moon NEARER or FARTHER from us when upon the HORIZON ?

A. When the moon is on the horizon, it is about *four thousand* miles farther from us than when in the zenith; its apparent diameter, therefore, instead of appearing larger, ought to appear about a sixtieth part less.

Q. The number of stars seen on a cloudless night appears countless : is it REALLY SO ?

A. It is an *illusion :* we do not see anything like the number of stars which we are accustomed to think we do.

On the entire sphere of the heavens there are not above twenty stars of the first magnitude, and it is seldom that as many as six or eight of these can be seen at once. The number of stars of the second magnitude does not exceed fifty, and of these, twenty can seldom be seen at any one time. The stars of the third magnitude may amount to about two hundred, half of which can only be at the same time above the horizon. The smaller stars are much more numerous, but they are discernible with difficulty, and do not produce upon the mind the idea of multitude that we conceive.

Q. Why are we so often mistaken in respect to the ACTUAL DISTANCE of a conflagration at night ?

A. Light radiating from a centre rapidly *weakens* as the distance from the centre *increases*, being, for instance, only one-fourth part as intense at double the distance. The eye learns to make these allowances, and by the clearness and intensity of the light proceeding from the object, judges with considerable accuracy of the comparative distance. But a fire at night appears uncommonly brilliant, and therefore seems nearer than it really is.

Q. Why does the evening star rising over a hill-top appear as if situated directly OVER the TOP of the eminence ?

A. Because we make brightness and clearness to depend on *contiguity*, as it ordinarily does; and as the star is bright, we unconsciously think it near us.

Q. How is it that after looking at a brightly coloured object for some time we appear to see it even after the object is removed from our sight ?

A. It is the effect of the brilliant *complementary colours* used, as red upon a green ground; the impression made on the retina lasting for an appreciable interval after the figure has been moved.

CHAPTER XXXV.

ARTIFICIAL LIGHT.

Q. How is ARTIFICIAL light generally OBTAINED?

A. By the *combustion of inflammable matter.*

Q. Would all bodies, if SUFFICIENTLY HEATED, become LUMINOUS?

A. They *undoubtedly would.*

Q. When is a body said to be INCANDESCENT?

A. When it is sufficiently heated to *glow* or *shine.*

Q. At what temperature do solids become INCANDESCENT?

A. The temperature at which solids begin to shine in the dark is between 600° and 700° F.; but they do not appear luminous in broad daylight until they are heated to about 1,000° F.

Q. Is artificial white light found to contain the SAME COLOURS as solar light?

A. It is; and the red, yellow, and blue rays may be *separated* from it by a *prism.*

Q. In what respect does ARTIFICIAL LIGHT differ from SOLAR LIGHT?

A. It contains *heat* in two different states.

It contains simple, RADIANT HEAT, like that radiated from a body not luminous, and which may be separated by transmission through a plate of moderately thick glass; but the light so purified still heats any body which absorbs it, and still possesses calorific rays, associated with its luminous rays, like those in solar light, and, like them, susceptible of refraction.

Q. Is LIGHT always ACCOMPANIED by heat?

A. It is not; there is no heat recognisable by the most delicate instruments in the *light* of the *moon.*

Q. Why does a piece of old and decayed wood sometimes appear LUMINOUS in the DARK?

A. Because, during the process of decay and the transformation of its elementary particles, a *chemical action* is produced which evolves light.

Q. What TERM do we apply to such action and phenomena?

A. The term *phosphorescence;* and bodies exhibiting this peculiar light are called *phosphorescent bodies.*

Q. Is phosphorescence, when occurring naturally, ACCOMPANIED by HEAT?

A. It is *not.*

Q. Does PHOSPHORESCENCE occur in organised, LIVING BODIES, as well as in dead, decaying substances?

A. It is most frequently noticed in living, organised structures; but the animals exhibiting it all belong to the lower classes, and are principally *worms* and *insects*, as the common *fire-fly.*

Q. To what is the phosphorescence or luminous appearance of the OCEAN, often observed, especially in the tropics, due?

A. To the presence of a multitude of *little animals*, known as *medusæ.*

Q. Do PLANTS and FLOWERS ever emit a phosphorescent or spontaneous light ?

A. A sudden flashing light is often emitted on fine summer evenings, a little after sunset, by certain *yellow flowers.* Some tropical plants and flowers *shine all night.*

Q. How has this emission of light in plants been ACCOUNTED for ?

A. It has been supposed that they *absorb* light during the sunshine, and afterwards *liberate* it.

Q. Is the PUTREFACTION of animal bodies accompanied with phosphorescence ?

A. In *many instances:* it exhibits itself most readily in *putrid fish*, although it has been observed in the decomposition of nearly all animal substances.

Q. WHY has this luminous appearance been called phosphorescence ?

A. Because it *resembles* the light which a piece of *phosphorus* exhibits when exposed to the action of the atmosphere.

Q. How is it supposed that the fire-fly and other similar insects ARE ENABLED to produce luminosity ?

A. They eliminate a peculiar and, in most cases, a *liquid substance*, containing *phosphorus* or some other element, which combines at common temperatures with the oxygen of the air, or of water containing air, producing a faint luminous appearance.

CHAPTER XXXVI.

DOUBLE REFRACTION AND POLARISATION.

Q. When is a ray of light said to be REFRACTED ?

A. When, in passing from one medium to another of *different density*, it is *bent* from its course, or from a straight line.

Q. When is a ray of light said to be DOUBLY REFRACTED ?

A. If any transparent substance has an *unequal constitution*, or if we can produce in it an *inequality* of *elasticity* by mechanical pressure or by heat, the ray falling upon its surface undergoes *two refractions;* that is, the *single* pencil is divided into *two* pencils in passing through the medium.

Q. What SUBSTANCE shows most distinctly the phenomena of double refraction ?

A. A small crystal of *Iceland spar*, or crystallised carbonate of lime.

Q. If we look at a small object through such a crystal, how does it appear ?

A. If we look at an object, as a dot, a letter, or a line, through a plate of glass, it appears *single;* but if a plate of Iceland spar be held over them, a *double* image will be perceived, as two dots, two letters, two lines, &c.

Q. What is POLARISED LIGHT, and how was it DISCOVERED?

A. In 1808, Malus, a young engineer officer of Paris, was viewing through a double-refracting prism the light of the sun reflected from a glass window of one of the French palaces, and he observed some peculiar effects. The window accidentally stood open, like a door on its hinges, at an angle of 56°, and Malus noticed that the light reflected from this angle was entirely *altered* in its character, or became *polarised.*

Q. Explain how polarised light DIFFERS from other light.

A. Suppose we have a cylinder with a mirror at one end of it. If we point this to the sun, and receive the image on a distant screen, we may turn the cylinder round on its axis, and the reflected ray will be found to *revolve* constantly with it. But if now, instead of receiving the ray *direct* from the sun, we allow a beam, *reflected* from a glass plate, at an angle of about 54°, to fall upon the mirror, and then be reflected on the screen, it will be found that the point of light will *not* have the same *properties* as that previously examined; it will be *altered* in its degree of intensity as the cylinder turns round; will have points where it is very bright, and others where it will be lost in shadow.

If we allow the pencil of light to fall upon a plate of glass at any usual angle, a part of it will pass through the glass, and a part of it will be reflected. If we place a second plate of glass over the reflected ray, a second reflection will take place on whatever side of the ray the reflecting glass may be placed. But if the ray falls upon the second glass at an angle of 56° from the perpendicular, the light reflected by the first glass will be again reflected by the second, when the planes of the two glasses are parallel to each other; but if, without altering its angle to the horizon, we turn the second glass to the quarter of a circle, the light will be transmitted, not reflected; if we turn it another quarter, the light will be reflected, not transmitted. By this we prove that light reflected at an angle of about 56° has undergone some peculiar modifications.

Q. Why was light so modified called POLARISED light?

A. Because, when this curious property of light was first discovered, it was theoretically ascribed to a kind of *polarity* of such sort that each side of a ray of light was thought to have a character *different* from the two adjacent sides at right angles to it.

Q. To what has the beam of polarised light been COMPARED?

A. To a "long, flat, straight stick" having sides, the ordinary ray of light being regarded as *cylindrical.*

Q. Is light polarised by reflection from any OTHER substance than glass?

A. Light is polarised by reflection from *many different substances*, such as glass, water, air, ebony, mother-of-pearl, surfaces of crystals, &c. &c., provided that the light falls at a *certain angle* peculiar to *each surface.* This angle is called the *polarising angle.*

Q. How was Arago ENABLED to DEFINE the nature of the incandescent matter of the sun by means of the action of polarised light?

A. He ascertained, first, that light proceeding from such bodies as red-hot iron, glass, and liquids, under a *certain angle*, was *polarised light;* but the light proceeding, under the same circumstances, from an *inflamed gaseous substance*, such as is used in street illumina-

tion, is always in its natural state. Applying these observations to the sun, he discovered that the light-giving substance of the sun was of the nature of a *gas*, and not a red-hot solid or liquid.

Q. Does this phenomena of polarised light enable us also to tell whether the fixed stars shine by their OWN LIGHT, as the sun, or by REFLECTED LIGHT, as the moon?

A. It *does;* all reflected light, come from whence it may, acquires certain properties which enable us to distinguish it from direct light; and thus the astronomer is enabled to determine with infallible precision whether the light he is gazing on (and which, from its distance, has taken thousands of years to reach the eye) be inherent in the body itself, or derived from some source without.

Q. Suppose we look at the shadow of a man on smooth water, through a polarising prism: by turning the glass, we shall find that in a certain position the shadow of the man will DISAPPEAR altogether, while the man himself is SEEN with all DISTINCTNESS: why is this?

A. It is occasioned by much of the light on the water being *polarised* by *reflection;* and therefore, as before shown, it is incapable of a *second reflection* by the prism, while the common light from the man himself admits of a reflection to the eye.

Q. It is well known that, by looking into the water from a great height, we can see farther into its depth than when looking from a convenient height above the surface: why is this?

A. It is owing to the fact that much of the light polarised by reflection from the water, and which obscures the vision when we view the water from a near position, is *lost* to the eye when at a considerable height above it.

CHAPTER XXXVII.

ACTINISM, OR THE CHEMICAL INFLUENCE OF LIGHT.

Q. What is the meaning of the term "ACTINISM?"

A. It is the name applied to the *chemical agency* of the sun's rays.

Q. Besides heat and light, is there any OTHER distinct PRINCIPLE existing in the solar ray?

A. There is; the *chemical principle.*

Q. What is the meaning of the term "PHOTOGRAPHY?"

A. *Light drawing.* The use of this term is most unfortunate, for light does not exercise that influence in producing what are called photographic pictures, which is usually supposed to be the case.

Q. How do we know that a SEPARATE chemical principle exists in the solar ray?

A. Because we can separate it from *heat* and *light.* There are certain media through which, if we pass a solar ray, one or two of its elements may be *separated* from the others; thus, a ray of light

passes readily through a transparent *plate of alum*, but nearly all the heat is *absorbed*. Certain dark-coloured bodies allow nearly all the heat to pass, and obstruct the light. A *blue* glass *obstructs* nearly all the *light* and *heat* of the solar ray, but allows the chemical principle to pass freely; while a *yellow* glass allows light and heat to *pass*, but obstructs the passage of the *chemical influence*.

Q. To what may the constitution of the solar ray be COMPARED?

A. To a bundle composed of three sticks: one representing *heat*, another *light*, and a third the *actinic* power—any one of which may be in a great degree separated from the other.

Q. When we decompose light by means of a prism, and throw the spectrum upon a screen, what are the RELATIVE POSITIONS assumed by the three different principles?

A. All these principles will be *refracted*, but the *calorific principle least* of any. Its maximum point will be found but slightly thrown out of the right line which the solar ray would have traversed had it not been intercepted by the prism, and the heating action will be found to diminish with much regularity on each side of this line.

Q. What will be the POSITION of the luminous principle?

A. It will be found to be subject to a *greater refraction*, its point of maximum intensity being in the yellow ray, lying considerably *above* the point of greatest heat. The light diminishes on each side of it, producing orange, red, and crimson colours below the maximum point, and green, blue, and violet above it.

Q. What will be the POSITION of the chemical or actinic principle?

A. The radiations which produce the chemical change are more refrangible than either of the others, and the maximum of this power is to be found at the point where *light rapidly diminishes*, and where scarcely any *heat can be detected*.

Q. What CURIOUS FACT has the study of the chemical principle of light elicited?

A. That no substance can be exposed to the sun's rays without undergoing a *chemical change*.

Q. Does DARKNESS appear to be ESSENTIAL to the healthy condition of inorganic matter as well as organised structures?

A. From numerous examples, it would seem that the change in the condition of bodies which the sunlight effects during the *daytime* is *made up* during the hours of *night*, when that excitement is no longer influencing them.

Q. What ILLUSTRATION can you give of this?

A. If a photographic impression be caused upon a sensitive surface at *night*, and no expedient for rendering it *permanent* be adopted, it *fades away* before morning, and we try to evoke it in vain.

Q. Why do colours FADE when exposed to the sunlight?

A. The materials of which the colours are composed become *changed* and *altered* through the action of the actinic principle of solar light.

Q. Upon what PRINCIPLE does the process of forming the daguerreotype and other photographic pictures DEPEND?

A. Solely upon the *actinic* or *chemical influence* of light.

Q. WHO made the first definite experiments which led to the discovery of the daguerreotype?

A. *M. Niepce*, a Frenchman of Chalons.

Q. What did he DISCOVER?

A. He ascertained that when a surface was covered with resin, and exposed to the solar rays, that the portion on which the *bright light* fell became much *more soluble* than those parts which had been influenced by the *weaker rays*, and could consequently be *dissolved off* before the other portion; thus an imperfect picture could be formed.

Q. WHO PERFECTED the discovery thus made?

A. *M. Daguerre*, of Paris, from whom the process derives its name.

Q. What did he DISCOVER?

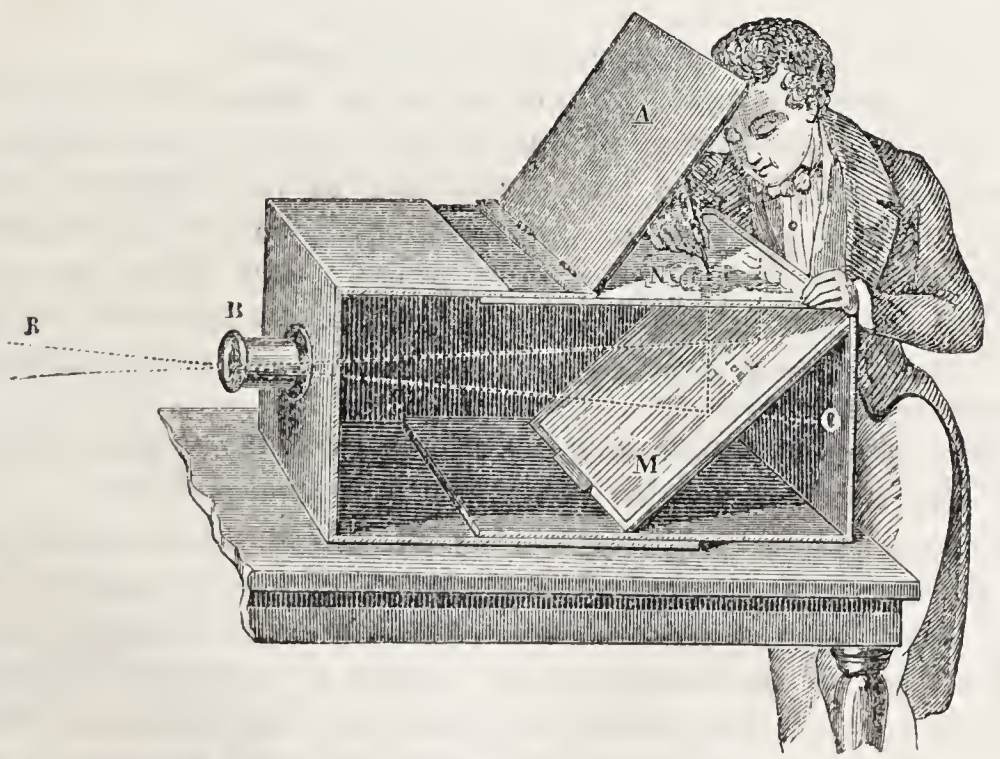
A. He ascertained that several compounds of silver were most easily affected by the action of light; those parts upon which the light fell *brightly* being *quickly decomposed*, while those portions protected by the *shadow remained untouched.* He also discovered a method of *fixing* the image thus drawn.

Q. What is a CAMERA OBSCURA?

A. In its original state it was nothing more than a *dark room*, with a very small opening, into which was fitted a *lens.*

If we make such an arrangement, and hold a sheet of white paper a few feet behind the opening, a very perfect image of any external object will be delineated upon it.

Fig. 113.



In t is diagram (fig. 113) the camera, or dark chamber, is represented. It consists of a

wooden box, into which the rays, R, enter through the lens, B, and form a picture on the opposite side, O. The rays of light, R, encountering a glass mirror, M, change their direction, and the picture is formed on a screen of polished glass, N. By placing upon this screen a sheet of paper, we can make a true outline drawing of the picture. The screen, A, serves to intercept the light from the glass, N.

Q. What is the PROCESS for taking a daguerreotype?

A. The production of a daguerrotype picture consists in preparing a *silver plate* by exposing it to the influence of *iodine*, and the vapour of bromine water. The plate is then exposed to the image formed by the *lens* of a *camera obscura*. Relatively, the quantity of light and actinism reflected from any object is the same; therefore, as the light and shadows of the luminous image vary, so will the power of producing change upon the plate vary, and the result will be the production of an image which will be a *faithful copy of nature*, with reversed lights and shadows; the *lights darken* the plate, while it is preserved *white* in the *shadows*.

Q. If the plate were then left without further care, what would HAPPEN to the image formed?

A. It would soon *fade away*, and leave no trace upon the plate.

Q. When the picture is taken from the camera, is there any IMAGE VISIBLE?

A. If the plate were allowed to remain a *sufficient time*, the image would be *visible;* but in practice it is not allowed to assume this condition. After an exposure of a *few seconds*, the radiant influence is *cut off*, and *no trace* of an image can then be detected on the plate, even with the aid of a *magnifying power*.

Q. How, then, is the picture DEVELOPED, or brought out, and rendered PERMANENT?

A. It is exposed to the *vapour of mercury;* and this metal, in a state of very fine division, is *condensed* upon the surface of the plate.

Q. Is that condensation spread UNIFORMLY upon its surface?

A. It is *not:* in exact proportion to the *amount* of *chemical action* produced, is the *deposit* of mercurial vapour, each layer being relatively to every other one, according to its thickness, an exact *measure* of the quantity of *solar action*. Where the *shadows* are *deep* there is scarcely a *trace* of mercury; and where the *lights* are *strong* the metallic globules are deposited of *considerable thickness*.

Q. What is the REASON that the mercury attaches itself only to those parts affected by the chemical influence of light?

A. We do not know how to *account* for it *satisfactorily;* in all probability, we have the involved action of *several forces*.

Q. Is it necessary that a surface should be CHEMICALLY PREPARED to exhibit this result

A. It is *not;* a *polished plate of metal*, a *piece of marble*, of *glass*, or *even wood*, when partially exposed to the action of light, will, when *breathed upon*, or presented to the action of *mercurial vapour*, show that a disturbance has been produced upon the portions which were *illuminated;* whereas no change can be detected upon the parts kept in the *dark*.

Q. Can a daguerreotype picture be taken in ABSOLUTE DARKNESS?

A. It *can*, in the following manner:—A large prismatic spectrum is thrown upon a lens fitted into one side of a dark chamber; and as we know that the actinic power resides in great activity beyond the violet ray, where there is no light, the only rays which we allow to pass the lens into the chamber are those beyond the limit of coloration, and non-luminous; these are directed upon any object, and from that object radiated upon a highly sensitive plate in a camera. Thus a copy of the subject will be produced by the agency of *radiations*, which produce *no effect* upon the *optic nerve.*

Q. By WHAT RAYS of the solar spectrum are VEGETABLE COLOURS most liable to be changed?

A. By the colours which are *complementary to them.*

Q. How do you ILLUSTRATE this?

A. A *red dye* or colour fades under the influence of a *green light*, and a *yellow* under that of a *blue light*, much more speedily than when exposed to rays of any other colour.

Q. What SUBSTANCE is used in nearly all the preparations of INDELIBLE INKS and washes for colouring the hair black?

A. A compound of silver: generally the salt known as *nitrate of silver*, or "*lunar caustic.*"

Q. WHY is this substance especially used?

A. Because it turns *black* under the influence of *light*, and *darkens* whatever substance it may be in contact with.

Q. Why does nitrate of silver TURN DARK when exposed to the action of light?

A. Because the chemical influence of light *decomposes* the *nitrate of silver*, and leaves only the *oxide of silver*, which is black.

Q. Is there any reason for supposing that each of the three principles (light, heat, and actinism) included in a ray of solar light exercises a DISTINCT and PECULIAR INFLUENCE on VEGETATION?

A. There is *no doubt* of the fact; and also that solar light, at *different seasons of the year*, is in some way modified as respects the quantity it contains of these elements, in order to meet the wants of vegetation at different periods.

Q. What is supposed to be the PECULIAR INFLUENCE exerted by the actinic element on vegetation?

A. It is supposed to be an active agent in exciting *germination.* Seeds exposed to its influence germinate with *great rapidity*, while if exposed to the influence of light deprived of its chemical element, they will *not germinate at all.*

Q. Is this principle found to be MORE ACTIVE at any one portion of the year than at another?

A. It is in the *spring*, at which time solar light possesses an excess of this influence.

Q. What PART is light supposed to play in the development of vegetation?

A. It is by the influence of the luminous ray that *carbon is secreted* from the *atmosphere*, and the woody tissues of the plant built up.

Q. Is this principle more active and abundant at ONE SEASON than at ANOTHER?

A. It is more abundant in the *summer* than at any other period. Light and actinism together are essential to the production of the colouring matter of leaves and flowers.

Q. What PART is the peculiar calorific element of the solar ray supposed to exert in the process of vegetation?

A. It facilitates the *flowering* of plants, and the *production* and *ripening* of *seeds* and *fruits*.

Q. Is this principle MORE ACTIVE at one season than at another?

A. In the *autumn* light and actinism both *diminish*, and *calorific radiations* are relatively to them the most extensive.

Q. How MUCH QUICKER will seeds germinate under a blue glass than when exposed freely to the full action of light?

A. Seeds which ordinarily require *ten* or *twelve days* for germination, will germinate under a *blue glass* in *two* or *three*.

Q. Why will seeds germinate MORE READILY under a BLUE glass than in any other condition?

A. Because the blue glass permits the *chemical principle* of light to *pass freely*, and excludes in a degree the heat and light.

Q. If we expose a seed under a STRONG LIGHT, but with all the necessary conditions of warmth and moisture, will it germinate?

A. It will *not*; the action of the light prevents germination, for the full success of which *shade* or *darkness* is necessary.

Q. Why is it impossible to make seeds germinate under a YELLOW GLASS?

A. Because a yellow glass *excludes* all the *chemical influence* of the solar ray.

Q. How do plants acquire the CARBON of which their structure is in a great measure composed?

A. They obtain it from *carbonic acid*, which they abstract from the atmosphere under the influence of light.

Q. Why are plants grown in the dark COLOURLESS?

A. Because they have no power to lay up *chlorophyl*, the green colouring matter of plants. This substance is principally composed of carbon. In the dark the plant still requires carbon for its further development; and, being unable to obtain it from the air, it removes it from the leaves, decomposing the chlorophyl, and thus supports its weak existence by preying on parts of its own structure, until at length, this being exhausted, it actually *perishes of starvation*.

ELECTRICITY.

CHAPTER XXXVIII.

NATURE AND PRODUCTION OF ELECTRICITY.

Q. What is ELECTRICITY ?

A. Electricity is one of those *imponderable* (that cannot be weighed) *agents* that appear to be diffused through *all nature*, existing in all substances without affecting their volume or their temperature, or giving any indication of its presence when in a latent state. When, however, it is liberated from this repose, it is capable of producing the most *sudden* and *destructive effects*, or of exerting powerful influences by a quiet and long-continued action.

Q. Was ELECTRICITY known to the ANCIENTS ?

A. Yes; they knew that when amber (the Greek word of which is ηλεκτρον, electron) is *rubbed* it acquires the power of *attracting* other bodies.

Q. WHO first noticed this property of amber ?

A. *Thales of Miletus ;* and it is from this Greek philosopher that we must date the commencement of our knowledge respecting this great natural agent.

Q. How may electricity be called into ACTIVITY ?

A. By *mechanical power*, by *chemical action*, by *heat*, and by *magnetic influence.*

Q. What is the most ORDINARY WAY of exciting electricity ?

A. By *friction.*

Q. Do we know any REASON why the means above enumerated should develope electricity from its latent condition ?

A. We are *entirely ignorant* upon this subject, and do not know whether electricity is a material agent, a property of matter, or vibrations of an ether.

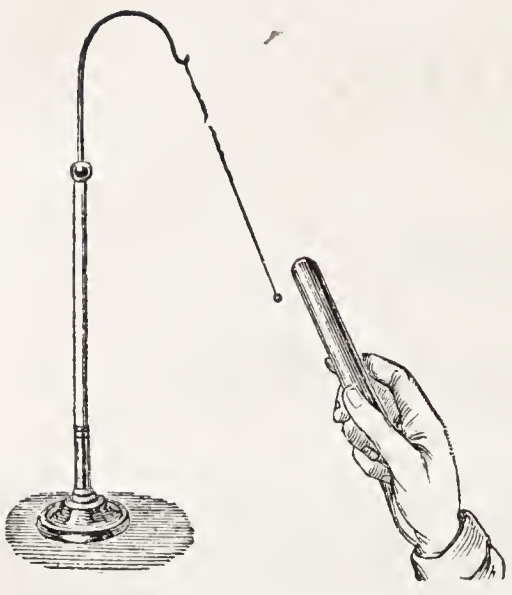
Q. When you rub a piece of paper with INDIA-RUBBER, why does it adhere to the TABLE ?

A. Because the friction of the india-rubber against the surface of the paper developes *electricity*, to which this adhesiveness is mainly to be attributed.

Q. Does electricity present any APPEARANCE by which it can be known ?

A. No; electricity, like heat, is in itself *invisible*, though often accompanied by both *light* and *heat.*

Fig. 114.



Q. How can we ASCERTAIN that a substance, whether by friction or other means, has been electrified?

A. This can be ascertained by means of small instruments, called *electroscopes;* the most simple of which is the *electric pendulum.*

This apparatus (see fig. 114) consists of a small pith ball, hung by a silk thread to a support with a glass foot. When an electrified body is brought near the ball, it is attracted, and then repelled immediately after contact.

Q. Is electricity accompanied with any ODOUR?

A. Yes; near a large electrical machine in good action there is always a *peculiar sulphurous odour*, which is ascribed to the production of a peculiar modification of oxygen, called "ozone."

Q. Has this peculiar odour, called "OZONE," been observed in THUNDER-STORMS?

A. It has; especially in and about *places* and *objects* struck with *lightning.*

Q. Why are there DIFFERENT COLOURS in the aurora borealis, such as white, yellow, red, and purple?

A. Because it is supposed that the electric current producing the aurora passes through air of different densities. The most rarefied air produces a white light; the most dry air, red; and the most damp produces *yellow streaks.*

Q. When a substance, by friction or by any other means, acquires the property of attracting other bodies, in what STATE is it said to be?

A. It is said to be *electrified*, or *electrically excited;* and its motion towards other bodies, or of other bodies towards it, is ascribed to a force called *electric attraction.*

Q. Does an electrified body exercise any OTHER INFLUENCE than an attractive one?

A. It *does;* for it will be found that light substances, after *touching* the electrified body, will *recede from it* just as actively as they approached it before contact. This is termed *electric repulsion.*

Q. What is a NON-ELECTRIFIED body?

A. One that holds its own natural quantity of electricity *undisturbed.*

Q. What HAPPENS when an electrified body touches one that is non-electrified?

A. The electricity contained in the former is *transferred* in part to the latter.

Thus, on touching the end of a suspended silk thread with a piece of excited wax, the silk will be excited, as will be shown by its moving towards a book, piece of metal, or any other object placed near it, as already shown in fig. 114.

Q. Do ALL BODIES conduct or allow electricity to pass through them equally well?

A. Although there is no substance that can *entirely prevent* the

passage of electricity, nor any that does not oppose *some resistance* to its passage, yet it moves with a much greater facility through a certain class of substances than through others. Those substances which facilitate its passage are called *conductors;* those that retard or almost prevent it, are called *non-conductors.*

Q. What SUBSTANCES are good CONDUCTORS of electricity?

A. The *metals*, *charcoal*, the *earth*, *water*, and *most fluids* (except *oils*), the *human body*, &c. &c., are good conductors.

Q. What substances OBSTRUCT the passage of electricity, or are, as they are sometimes called, "non-conductors?"

A. Glass, *resin*, *oils*, *silk*, *sulphur*, *dry air*, &c. &c., are non-conductors.

The old notion that some bodies were electrics or non-conductors, and others non-electrics or conductors—that is to say, that some substances were capable of becoming electrical, and that others were not—is incorrect. Everything in nature is capable of conducting electricity more or less; there is neither a perfect conductor nor one totally incapable of conduction. The difference is of degree, and not of kind.

Q. When a body capable of being easily electrified is surrounded or insulated from all other conductors by means of non-conducting substances, can electricity be ACCUMULATED in it?

A. It can to a *very great extent;* but as all substances conduct electricity more or less, the surplus quantity will *gradually pass off.*

Q. Does the SHAPE of the body have any influence in retaining electricity?

A. It *does:* it is more easily retained by a *sphere* than by a *spheroid* and a *cylinder;* but it readily escapes from a point, and a pointed object receives it with the greatest facility.

Q. Does there appear to be a DIFFERENCE between the kind of electricity excited by rubbing a piece of GLASS and that excited by rubbing a piece of WAX or RESIN?

A. The electricities developed in these two ways are *essentially different;* and hence it has been inferred that there are two kinds or states of electricity—the one called *vitreous*, because especially developed on glass; and the other *resinous*, because first noticed on resinous substances.

Q. How does this DIFFERENCE MANIFEST itself?

A. If two substances are charged with *vitreous* electricity, they *repel* each other; two substances charged with *resinous* electricity also *repel* each other; but if one is charged with *vitreous*, and the other with *resinous* electricity, they *attract* each other.

Q. What THEORY is based upon these phenomena of attraction and repulsion by the different kinds of electricity?

A. The theory of *Du Fay*, or the theory of *two fluids.*

Q. What does this theory SUPPOSE?

A. It supposes an exceedingly *thin* and *subtle fluid* pervading the most compact bodies, which is composed of two ultimate elements, namely, the *vitreous* and the *resinous* electricities. Each kind is supposed to *repel its own particles*, but *attract* the particles of the *other kind.*

Q. What OTHER THEORY has been proposed to account for the phenomena of electricity?

A. The theory of a *single fluid*, or the *Franklinian theory*, so called from its having originated with Dr. Franklin.

Q. What does this theory SUPPOSE?

A. It supposes the existence of a *single*, *imponderable* (that cannot be weighed), *subtle fluid* equally distributed throughout nature. Every substance, organic or inorganic, being so constituted as to retain a certain quantity of this agent, which is necessary to its physical condition, but when, in repose, offering no evidence of electrical presence. Any disturbance of the natural state of a body produces evidences of electricity.

Q. How does this theory explain the REASON of the differences in the electricity developed by GLASS and RESIN?

A. It supposes *electrical excitation* to arise from the difference in the relative quantities of this principle existing in the body rubbed and the rubber, or in their powers of receiving and retaining electricity.

Thus one body becomes overcharged by having abstracted this principle from the other.

Q. What NAMES did Franklin, in accordance with the theory, apply to the two different conditions of electricity, called by Du Fay vitreous and resinous?

A. *Positive* and *negative*, or *plus* and *minus*. Thus a body which has an overplus of electricity is called positive, and one that has less than its natural quantity is called negative.

Q. What THEORY has lately been proposed by Professor FARADAY respecting the nature of electricity?

A. He considers it a mere *power of matter*, like what we conceive of the attraction of gravitation.

Q. Do light, heat, and electricity appear to have some properties IN COMMON?

A. They *do;* each may be made, under certain circumstances, to *produce* or *excite* the other. All are so light, subtle, and diffusive, that it has been found impossible to recognise in them the ordinary characteristics of matter. Some suppose that light, heat, and electricity are all *modifications* of some common principle.

Q. Why does the FUR of a CAT sparkle and crackle when rubbed with the hand in cold weather?

A. Because the friction between the hand and the fur produces an excitation of *positive electricity* in the *hand* and *negative* in the *fur*, and an interchange of the two causes a spark, with a slight noise.

Q. Why does this experiment work best in very COLD WEATHER?

A. Because the air is then *very dry*, and does not *convey away* the electricity as fast as it is excited; if the air, on the contrary, were *moist*, the electricity would be *conducted off* nearly as fast as it was excited by friction, and its effects would not therefore be so manifest.

Q. With what VELOCITY is electricity transmitted through good conductors?

A. With a velocity so great that the most rapid motion produced

by art appears to be actual rest when compared to it. Some authorities have estimated that electricity will pass through copper wire at the rate of *two hundred and eighty-eight thousand miles in a second* of time—a velocity greater than that of light. The results obtained, however, by experiments with iron wire, show a velocity of from 15,000 to 20,000 miles per second.

Q. Is a perfect conductor AFFECTED by the passage of a current of electricity?

A. If it be of sufficient *size* to carry off the whole easily, it is *not affected;* but it is shivered into pieces in an instant if it happens to be too small: this also happens to a very bad conductor.

Q. What AGENTS are undoubtedly the most ACTIVE in producing and exciting electricity in the operations of nature?

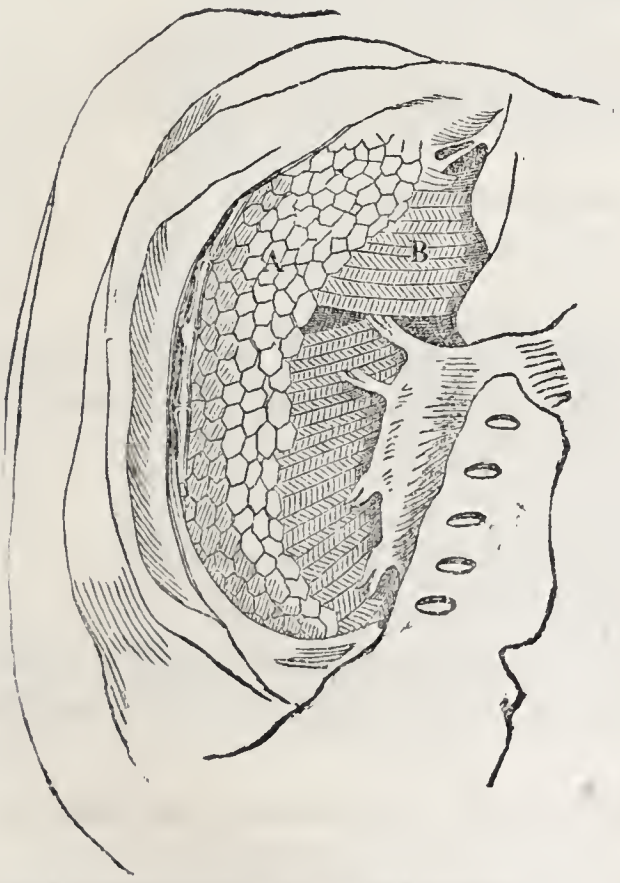
A. The *light* and the *sun's rays.*

Q. It has become the habit with many to ascribe to electricity the agency of phenomena in the natural world, the cause of which may not be apparent: is there any REASON for this?

A. There certainly is not; electricity is *diffused through all matter*, and is ever active, and many of its phenomena cannot be satisfactorily explained; but it is governed, like all other forces of nature, by certain fixed laws, and it is by no means a necessary agent in all the operations of nature.

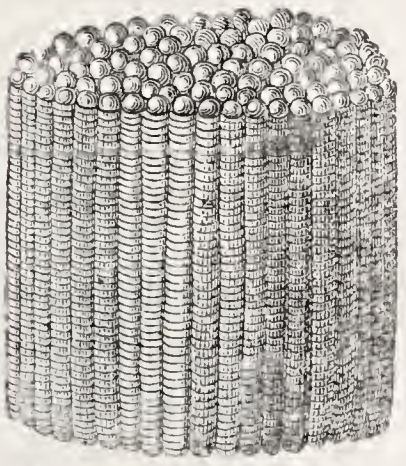
It argues great ignorance to refer, without examination, every mysterious phenomena to the influence of electricity.

Fig. 115.



ELECTRICAL ORGAN OF THE TORPEDO.
A, transverse section; B, position of prisms, or seat of electricity.

Fig. 116



PERPENDICULAR SECTION OF PRISMS.

Q. Do some animals have the power of exciting electricity WITHIN THEMSELVES?

A. There *are* certain animals which are *gifted* with the extraordinary power of *producing electrical phenomena* by an effort of muscular or nervous energy. Among these the electrical eel and the torpedo are most remarkable. (*See figs.* 115, 116.)

Q. How powerful a charge of electricity can the ELECTRICAL EEL send forth when in full vigour?

A. Sufficient to *knock down a man* or *stun a horse.*

Q. Is the electricity generated by these animals the SAME as that occasioned by the ORDINARY ELECTRICAL MACHINE?

A. It *is the same*, and produces the *same effects.*

Q. Do VITAL ACTION and MUSCULAR MOVEMENTS in man and animals give rise to electricity?

A. They *do;* and it can be shown by direct experiment that a person cannot even *contract the muscles of the arm* without exciting an electrical action.

Q. Does CHANGE of FORM or STATE in bodies generally produce electrical excitation?

A. Change of form or state is one of the *most powerful methods* of exciting electricity.

Water, in passing into steam by artificial heat, or in evaporating by the action of the sun or wind, generates large quantities of electricity. The crystallisation of solids from liquids, all changes of temperature, the growth and decay of vegetables, are also instrumental in producing electrical phenomena.

ELECTRICAL MACHINES.

Q. By whom was the FIRST ELECTRICAL MACHINE invented?

A. *Otto de Guericke*, who also invented the *air-pump.*

Q. How was it FORMED?

A. It consisted of a *ball of sulphur* fixed to an axis turned with *one hand*, while the other *rested* on the sphere, and served to *rub* it.

Q. What was the NEXT IMPROVEMENT?

A. The *ball of sulphur* was exchanged for a *glass cylinder.*

Q. What IMPROVEMENT was introduced by WINKLER?

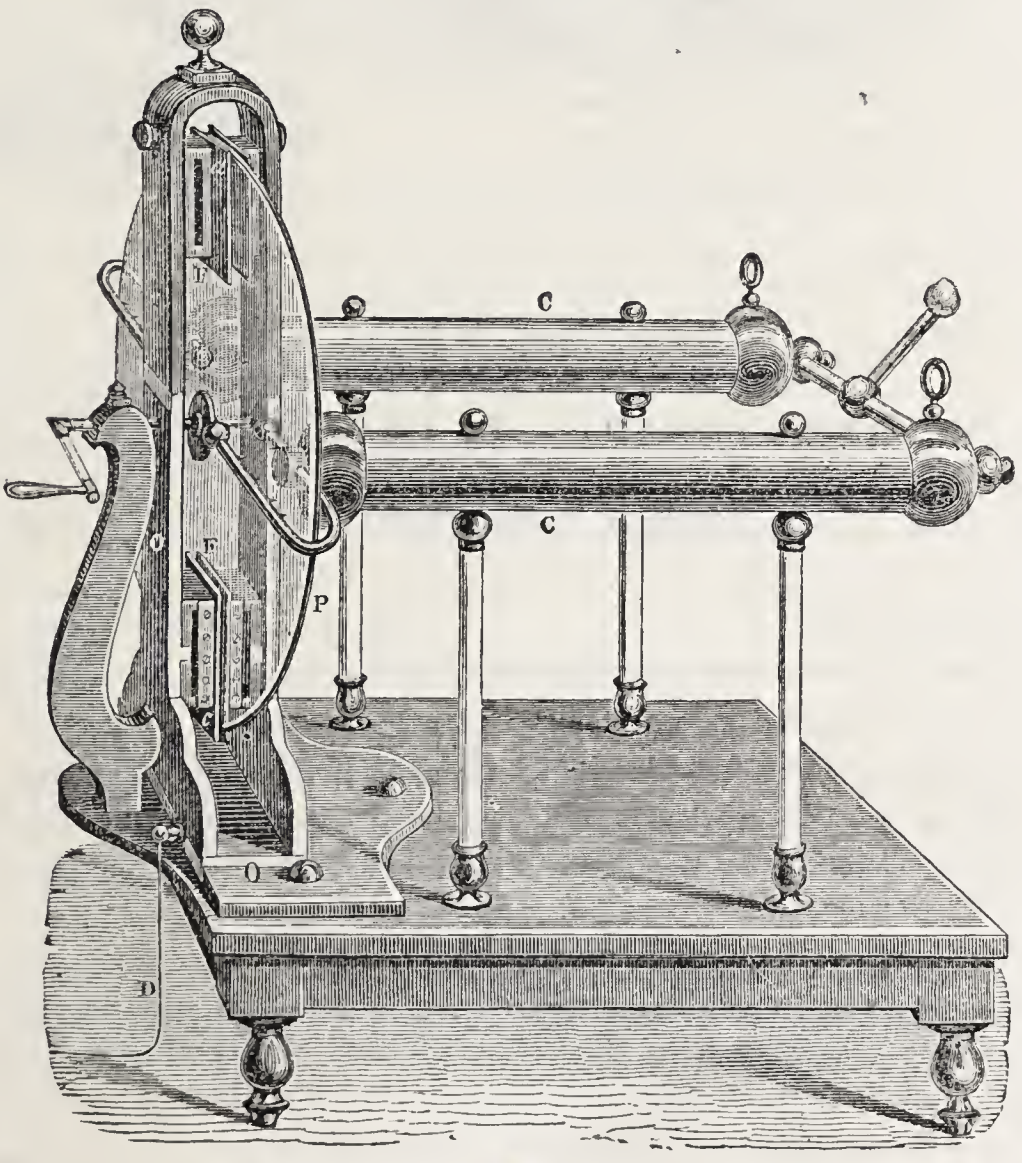
A. In 1740, Winkler, a German philosopher, substituted *a horse-hair cushion, covered with silk*, instead of the *hand*, for *rubbing* the *cylinder.*

Q. When were such ELECTRICAL MACHINES as are now commonly used FIRST employed?

A. The present ordinary form of the electrical machine was introduced by Mr. Ramsden in London about 1766. It consisted of a *glass plate rubbed by cushions.*

Fig. 117 represents an electrifying machine. Between two wooden supports is a circular glass plate, P, fixed at its centre to an axis, and turned by a winch. This plate is pressed by four leather pads, called RUBBERS, F. Two brass tubes, called COMBS, face the plate, and are fixed to two larger tubes, C, called CONDUCTORS, which stand on four glass legs. As the glass plate is moved round it is electrified positively, and the cushions negatively. These latter lose their electricity by communicating it to the earth through the wooden supports as soon as it is produced. The positive electricity of the plate acts on the conductors, and attracts the negative fluid, which combines with the positive electricity of the glass, and neutralises it. The conductors, which thus lose their negative electricity, therefore, remain positively electrified. The machine, being once charged, on placing the hand near it, a strong spark is elicited, which is repeated as long as the plate continues to be turned; for the spark being the result of the combination of the negative fluid of the hand with the positive fluid of the machine, the latter tends at each spark to return to the neutral state, but the influence of the plate excites it afresh.

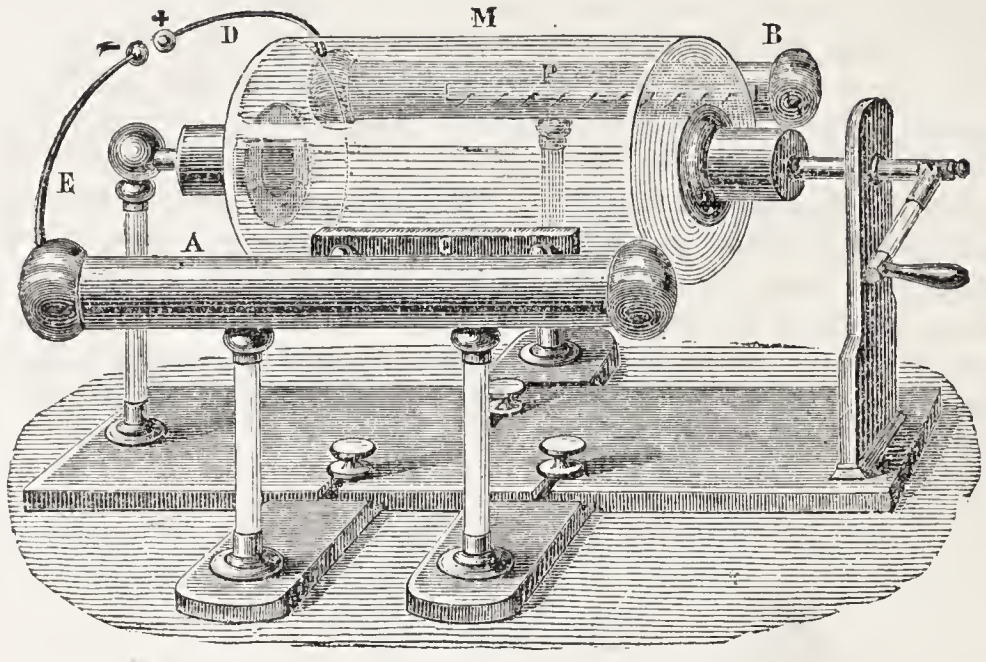
Fig. 117.



In fig. 118 we have represented Nairne's electrical machine. It is formed of two conductors, which do not touch one another; the one has a rubber, C, made of leather, and stuffed with horse-hair; the other a comb, P, formed with several teeth. Between them is a glass cylinder. When turned, this glass cylinder excites electricity, negative

and positive, given forth in a series of sparks at the copper balls ending the curved branches D and E.

Fig. 118.



CHAPTER XXXIX.

ATMOSPHERIC ELECTRICITY.

SECTION I.—LIGHTNING.

Q. What is LIGHTNING ?

A. *Electricity* accumulated *in* and discharged *from the clouds.*

Q. By what means is this ELECTRICITY in the CLOUDS produced ?

A. By the *evaporation* from and the *chemical changes* which take place on the earth's surface, together with the expansion, condensation, and variation of temperature of the atmosphere and of the moisture contained in it.

Q. Does the amount of electricity in the air VARY at DIFFERENT ALTITUDES ?

A. The electricity of the air *increases in strength with the altitude.* It is sometimes different in the lower regions from what it is in the upper, being positive in one and negative in the other.

Q. How is the AMOUNT of electricity in the air DETERMINED ?

A. By means of an *electrometer.*

Q. What is an ELECTROMETER ?

A. It is an instrument which serves to *indicate* and *measure electricity.* The one often used consists of a glass jar, surmounted by a

pointed metallic rod, to the lower end of which, within the jar, two fine straws are loosely attached. The pointed rod collecting the electricity from the air, the two straws become similarly electrified, and recede from each other. The amount of divergence measures the quantity of the fluid.

Fig. 119.

In the accompanying diagram (fig. 119) is shown what is called BENNETT'S ELECTROMETER. It consists of a glass jar, B, resting upon a plate of copper, and having its neck stopped by a cork. Through the cork passes a copper wire, having a ball, C, at one end, and two pieces of very thin gold-leaf at the other, inside the jar. When a body charged with electricity (negative) is brought near, this electricity acting upon the neutral fluid of the ball and the wire, the positive fluid in the ball is attracted, and the negative repelled, towards the pieces of gold-leaf, which, being charged with the same kind of electricity, repel each other. Thus we see that the substance A is electrised. Different other experiments of the same nature may be made with this apparatus.

Q. What SORT of ELECTRICITY pervades the atmosphere, or in what CONDITION is it generally ?

A. In the ordinary state of the atmosphere its electricity is *invariably positive.*

Q. Under what CIRCUMSTANCES does the electrical condition of the atmosphere CHANGE ?

A. When the sky is *overcast*, and the clouds are moving in different directions, the atmosphere is subject to great and sudden variations, rapidly changing from positive to negative, and back again, in the space of a few minutes.

Q. When is the atmosphere MOST HIGHLY charged with electricity ?

A. When *hot weather* succeeds a *series of wet days*, or *wet weather* follows a succession of *dry days.*

Q. Is there more of electricity at ONE SEASON in the atmosphere than at another

A. There is more electricity in the atmosphere during the *cold of winter* than in the summer months.

Q. Is electricity ADDED to the atmosphere during the PROCESS of COMBUSTION ?

A. When a substance is burning, *positive electricity escapes* from it into the atmosphere, while the substance itself becomes negatively electrified. Thus the air becomes the receptacle of a vast amount of positive electricity generated in this manner.

Q. What CAUSES the DISCHARGE of an ELECTRIC CLOUD ?

A. When a cloud *overcharged* with electric fluid approaches another which is *undercharged*, the fluid rushes from the former *into the latter*, till both contain the *same quantity.*

Q. Is there any OTHER CAUSE of LIGHTNING besides the one just mentioned?

A. Yes; sometimes mountains, trees, and steeples will discharge the lightning from a cloud floating near, and sometimes electric fluid passes from the earth into the clouds.

Q. What is the ESTIMATED HEIGHT of LIGHTNING-CLOUDS above the earth?

A. Their height varies from *five miles* to a *few feet* above the earth's surface. The usual height in a storm is 700 yards.

Q. What is a THUNDER-STORM?

A. The *disturbance* caused in the *air* when successive discharges of accumulated electricity take place.

Q. How do thunder-storms occur, as regards LATITUDE and TIME?

A. They prevail most in the *torrid zone*, and decrease in frequency towards either pole. In the Arctic regions thunder-storms seldom or never occur. As respects time, they are most frequent in the *summer months.*

Q. Why should the DISCHARGE of ELECTRICITY from cloud to cloud, or from a cloud to the earth, produce the VIVID FLASH of light which we call lightning?

A. When a portion of air is subjected to a very *sudden* and *powerful compression*, a spark is elicited. It can be proved that electricity produces such compression; and it is to the almost instantaneous condensation of the atmosphere before the electric fluid, as it darts from point to point, that the vivid flash we see is attributed.

Q. Into how MANY KINDS has lightning been divided?

A. Three.

Q. What ARE THEY?

A. The *zigzag lightning*, *sheet lightning*, and *ball lightning.*

Q. Why is lightning sometimes FORKED?

A. Because the lightning cloud is at a *great distance;* and the *resistance of the air* is so great, that the electrical current is diverted into a zigzag course.

Q. How does the RESISTANCE of the AIR make the lightning ZIGZAG?

A. As the lightning condenses the air in the immediate advance of its path, it flies from side to side, in order to pass where there is the *least resistance.*

Q. Why is the FLASH sometimes quite STRAIGHT?

A. Because the lightning cloud is near the earth, and as the flash meets with very little resistance, it is not diverted; in other words, the flash is straight.

Q. What is SHEET LIGHTNING?

A. Either the reflection of distant flashes not distinctly visible, or beneath the horizon; or else *several flashes intermingled.*

Q. What OTHER FORM does lightning assume?

A. Sometimes the flash is *globular*, which is the most dangerous form of lightning.

Q. How is BALL LIGHTNING supposed to be produced?

A. Philosophers have not yet been able to account for lightning of this description: it has, however, been supposed to arise from an *uninterrupted discharge* of electricity.

Q. Does a discharge produce a FLASH when it passes through GOOD conductors?

A. It does *not*, but passes quietly and invisibly.

Q. What is HEAT LIGHTNING?

A. Sometimes it is the *reflection* in the atmosphere of the lightnings of storms *very remote*, the storms themselves being so far distant that their thunders cannot be heard. This phenomenon is also occasioned by the play of silent flashes of electricity between the earth and the clouds, the amount of electricity developed not being sufficient to produce any other effects than the mere flash of light.

Q. When lightning flashes from the earth to the clouds, what is the flash CALLED?

A. It is popularly called the "*returning stroke;*" because the earth (being overcharged with electric fluid) *returns* the surplus quantity to the clouds.

Q. When does lightning pass FROM THE EARTH to the CLOUDS?

A. When the clouds are in a "*negative*" state of electricity.

Q. When does lightning pass FROM THE CLOUDS to the EARTH?

A. When the clouds are in a "*positive*" state of electricity.

Q. What is generally meant by the clouds being in a "POSITIVE STATE" of electricity?

A. When the clouds contain *more electric fluid* than they generally do, they are said to be in a "positive state of electricity."

Q. What is generally meant by the clouds being in a "NEGATIVE STATE" of electricity?

A. When the clouds contain *less electric fluid* than they generally do, they are said to be in a "negative state of electricity."

Q. Does the flash proceed from a NEGATIVE or POSITIVE body?

A. Always from a *positive body;* that is, from one *over*-charged with electric fluid.

Q. How LONG is the DURATION of a flash of lightning?

A. Arago has demonstrated that it does not exceed the *millionth part of a second.*

Q. With what VELOCITY is lightning, or the electric fluid which gives rise to its appearance, supposed to MOVE?

A. Not less than *two hundred and fifty thousand miles per second.*

SECTION II.—EFFECTS OF LIGHTNING.

Q. Is there ANY DANGER attending LIGHTNING?

A. Yes; its effects are sometimes *fatal.*

Q. How are the EFFECTS of LIGHTNING fatal?

A. By the electric fluid passing through the *living body*, and producing so violent an action on the nervous system that death ensues.

Q. Will LIGHTNING, then, pass through the LIVING BODY ?

A. Yes; if that body *intercept* its passage to the earth.

Q. What is the SAFEST thing a person can do to avoid injury from lightning ?

A. Lie upon a *bed* in the *middle* of a room. A bed filled with feathers is an excellent non-conductor.

Q. Is there not generally a GREATER FEAR of the danger from lightning than experience would JUSTIFY ?

A. The apprehension and solicitude respecting lightning are proportionate to the magnitude of the evils it produces, rather than the frequency of its occurrence. The chances of an individual being killed by lightning are *infinitely less* than those which he encounters in his daily walks, in his occupation, or even during his sleep from the destruction of the house in which he lives by fire.

Q. How are the MECHANICAL EFFECTS of lightning displayed ?

A. In *piercing solid bodies* with holes, in splitting them in pieces, and in projecting their fragments to great distances.

Q. How is it ACCOUNTED FOR that the mere passage of a current of electricity, as developed in a flash of lightning, can exercise such enormous mechanical power as to throw down buildings, shatter rocks, rupture masses of metal, &c. &c. ?

A. We know that the passage of lightning along metallic conductors often produces sufficient heat to melt them *instantly.*

Arago supposes that the heat of the lightning in passing through any substance may instantly convert all the moisture contained in it into steam of a highly explosive character, and that the great mechanical effects observed are due to this agent rather than to the direct effect of the electric current.

Q. How does Arago attempt to PROVE this ?

A. He states that the temperature which could instantly render iron *red hot* would be sufficient to generate steam of such an elastic force as would overcome *all* obstacles.

If the water contained in the pores of bodies were therefore at once converted into steam of this character, its force would be capable of producing any of the mechanical effects witnessed.

Q. What OTHER THEORY has been proposed to account for the effects of lightning ?

A. A theory which supposes that the natural electricities of non-conducting bodies being forcibly decomposed by the presence of the electric fluid which forms the lightning, and which may be considered to have an almost infinite intensity, their violent separation would *force asunder* everything which might tend to confine them or obstruct their passage.

Q. Why does the lightning in its course down a building generally DART from POINT to POINT, and not follow a DIRECT PATH ?

A. Because it always takes in its course the *best conductors;* and will fly both right and left in order to reach them.

Q. What EFFECT has a THUNDER-STORM on the ATMOSPHERE ?

A. It purifies the air by producing *nitric acid* and *ozone*, which dispel noxious vapours, and, by agitating the air, stirs up fresh breezes, rendering it more pure and healthy.

SECTION III.—LIGHTNING CONDUCTORS.

Q. What is a LIGHTNING CONDUCTOR?

A. A *metal rod*, intended to conduct the lightning to the earth.

Q. Why should LIGHTNING CONDUCTORS be POINTED?

A. Because points conduct electricity away *silently* and *imperceptibly.*

Blades of grass, ears of corn, and other pointed objects serve to withdraw electricity from the clouds.

Q. How FAR does the influence of a lightning conductor extend?

A. It will protect a space all round four times the length of that part of the rod which *rises above the building.*

Q. Give me an EXAMPLE.

A. If the rod rises *two feet* above the house, it will protect the building for (at least) *eight feet* all round.

The area of protection, however, varies according to conditions, "the protection being more or less complete according to the elevation of the rod, its size, its conducting power, the absence of other attracting objects in its vicinity, and some other circumstances. To demonstrate how small an area may be protected by a lightning rod, by reference to what has occurred, the following example may be cited :—The mainmast of H.M.S. Endymion was protected, the foremast not, and a flash of lightning striking the latter, shivered it to atoms ; yet the distance between the two masts was scarcely fifty feet."

Q. Can lightning conductors be productive of harm?

A. Yes; if the rod be *broken*, the electric fluid, being obstructed in its path, will enter the building; and if the rod be not large enough to conduct the *whole* current to the earth, the lightning will *fuse* the metal and enter the building.

Q. Is not AIR a CONDUCTOR of lightning?

A. No; dry air is not a conductor of lightning.

Q. By whom was the IDENTITY of lightning and electricity first established?

A. By *Dr. Franklin*, at Philadelphia, in 1752.

The manner in which this fact was demonstrated was as follows :—

Having made a kite of a large silk handkerchief stretched upon a frame, and placed upon it a pointed iron wire connected with the string, he raised it upon the approach of a thunder-storm. A key was attached to the lower end of the hempen string holding the kite, and to this one end of a silk ribbon was tied, the other end being fastened to a post. The kite was now insulated, and the experimenter for a considerable time awaited the result with great solicitude. Finally, indications of electricity began to appear on the string ; and on Franklin presenting his knuckles to the key, he raised an electric spark. The rain beginning to descend, wetted the string, increased its conducting power, and vivid sparks in great abundance flashed from the key.

Q. Why was the KITE INSULATED when Franklin fastened the key to the post with a SILK RIBBON?

A. Because the silk was a *non-conductor*, and would not allow the electricity received upon the kite to pass off by means of the string to the ground.

Q. Was this experiment one of GREAT DANGER and RISK?

A. It was; because the whole amount of electricity contained in

the thunder-cloud was *liable to pass from* it, by means of the string, to the earth, notwithstanding the use of the silk insulator.

Q. What HAPPENED when the experiment was subsequently repeated in France?

A. Streams of electric fire, *nine and ten feet in length, and an inch in thickness*, darted spontaneously, with loud reports, from the end of the string confining the kite. During the succeeding year, Professor Richman, of St. Petersburg, in making experiments somewhat similar, and having his apparatus entirely insulated, was *immediately killed.*

Q. What PRACTICAL RESULT flowed from Franklin's experiment?

A. The use of *pointed rods* to convey away electricity, and in this way to protect buildings, &c.

Q. Which METAL is the BEST to employ for a LIGHTNING CONDUCTOR?

A. Copper.

Q. If a lightning rod is made of IRON, how LARGE should it be?

A. Not less than *three-quarters of an inch* in diameter.

Q. In what MANNER should the rod be erected?

A. The rod should be continuous from the *top to the bottom*, and an entire metallic communication should exist throughout its whole length. This law is violated when the joints of the several parts that form the conductor are imperfect, and when the whole is loosely put together.

Q. How should the conductor be FASTENED to the building?

A. By *wooden supports.* If there are masses of metal about the building, as gutters, pipes, &c., these should be connected with the rod by strips of metal; for, unless this is done, the lightning may pass from the rod to the metal, and enter the building.

Q. How should the LOWER END of the rod be arranged?

A. It should be *divided* into *two or three branches*, and turned from the building. The end of the rod ought to extend so far below the surface of the ground as to reach earth that is permanently damp; or, if a mass of water be near, it is a good plan to extend the extremity of the rod into it.

Q. Why is it a good plan to BURY the end of the rod in POWDERED CHARCOAL?

A. Because it preserves the iron from *rust*, and *facilitates* the *passage* of the electricity.

Q. Have we any PROOF of the utility of lightning rods?

A. The experience of a hundred years has shown that when all the *necessary rules* have been *observed*, the protection is perfect, as far as human effort can avail.

Q. Is a building more or less liable to be struck when furnished with a good LIGHTNING CONDUCTOR?

A. Lightning conductors do *not*, as many suppose, *attract the lightning towards the building* on which they are situated; they simply *direct its course*, and *facilitate* the *passage* of the *fluid* in the most

direct way to the earth, only when a discharge must inevitably occur. There is no attraction, but the lightning takes the road which offers the least resistance.

Q. Are lightning conductors PROTECTIVE when even no visible discharge takes place?

A. They *are;* they possess a very great *preventive power*, and gradually and silently disarm the clouds by drawing the electric fluid from them; and this process commences as soon as the cloud has approached a position vertically over the rod.

Q. In what manner does Professor Faraday recommend that lightning conductors be ARRANGED?

A. He advises their location on the *inside* of buildings, rather than the outside.

SECTION IV.—THUNDER.

Q. What is THUNDER?

A. It is a certain *noise* proceeding apparently from the clouds, which usually follows, after a greater or less interval, the appearance of a flash of lightning.

Q. How is it supposed to be OCCASIONED?

A. The usual explanation offered is a *sudden displacement of the air*, produced by the electrical discharges, in which the lightning is evolved. Others have supposed that the passage of the electric current creates a vacuum, and that the air rushing in to fill it produces the sound. No explanation that has yet been offered is altogether satisfactory.

Q. What occasions the ROLLING of the thunder?

A. It has been ascribed to the *effect of echo;* but this, undoubtedly, is not the only cause. The rolling of thunder is heard as perfectly at sea as upon land; but there none of the causes which are generally supposed to produce echo, as mountains, hills, buildings, &c. &c., are present. Another and perhaps the true reason is, that the sound is developed by the lightning in passing through the air, and consequently separate sounds are produced at every point through which the lightning passes.

Q. Does THUNDER always SOUND exactly the SAME?

A. No; sometimes it has a *rolling sound*, as already described; sometimes the sound is *irregular;* sometimes it is a *loud crash.*

Q. Is not the LIGHTNING SEEN before we HEAR the THUNDER?

A. It is; light travelling *nearly a million times faster* than sound.

Q. Can we, then, ASCERTAIN the DISTANCE of the THUNDER-CLOUD by noticing how LONG a TIME INTERVENES between the FLASH and the SOUND?

A. Yes; it will take a *second of time* for thunder to travel 380 yards; therefore, if three seconds elapse between the flash and the sound, the thunder-cloud must be 1140 yards distant.

Q. What is a THUNDERBOLT ?

A. The appearances which uninformed persons call thunderbolts are nothing more than the *globular form* assumed sometimes by the electric fluid.

GALVANISM.

CHAPTER XL.

NATURE AND PRODUCTION OF GALVANIC ELECTRICITY.

Q. What is GALVANISM ?

A. It is the production of *electrical disturbance by chemical action.*

Q. How does galvanic electricity appear to DIFFER from frictional or ordinary electricity ?

A. The electricity developed by friction from a glass plate, or the cylinder of an electrical machine, is a discharge with a *sort of explosion*, whereas that which is generated by chemical action is a *steady, flowing current.*

Q. What is the most SIMPLE MANNER of illustrating the production of this electricity ?

A. If we place a piece of silver on the tongue, and a piece of zinc underneath it, no effect will be produced as long as the two metals are kept asunder; but when their ends are brought together, a *distinct thrill* will pass through the tongue, a metallic taste will diffuse itself, and, if the eyes are closed, a sensation of *light* will be evident at the same moment.

Q. To WHAT is this result OWING ?

A. To a *chemical action* developed the moment the two metals touched each other.

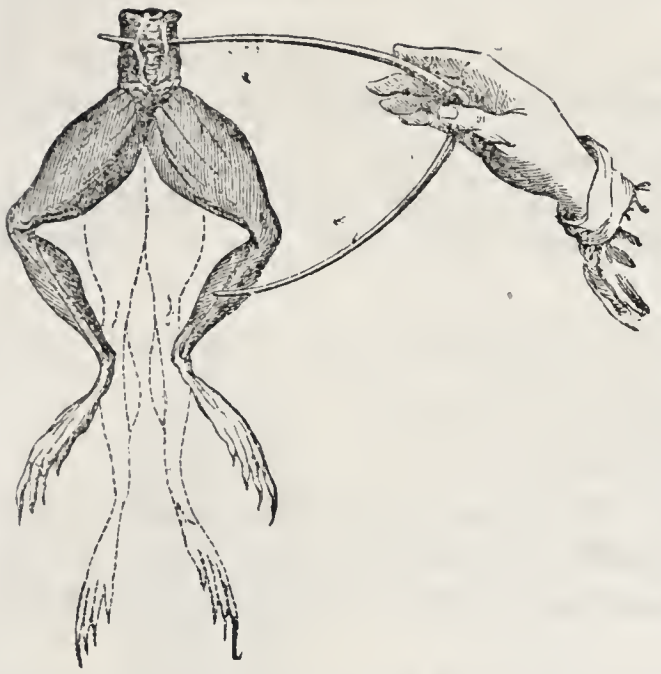
Q. What was this chemical action ?

A. The *saliva* of the tongue *oxydised* a portion of the *zinc*, which excited *electricity*, for no chemical action ever takes place without producing electricity. Upon bringing the ends of the two metals together a slight current passed from one to the other.

Q. By WHOM was the production of galvanic electricity first noticed ?

A. By *Galvani*, Professor of Anatomy at Bologna, Italy, in 1790.

Fig. 120.



Q. How was his attention DIRECTED to the subject?

A. Having occasion to dissect several frogs, he hung up their hind legs on some *copper hooks*, until he might find it necessary to use them for illustration. In this manner he happened to suspend a number of the copper hooks on an iron balcony, when, to his great astonishment, the limbs were thrown into violent convulsions.

Q. On investigating the phenomena, to WHAT did he attribute the cause?

A. He found that the mere contact of dissimilar metals with the moist surfaces of living muscles was all that was necessary to produce the convulsions. (*See fig.* 120.) He attributed the phenomena to *electricity* present in the muscles, and imagined that the metals served only as conductors.

Q. What was the REAL CAUSE of the convulsions?

A. A weak *chemical action*, greatly quickened by the contact of dissimilar metals.

Q. What is the SIMPLEST WAY of exciting a current of GALVANIC ELECTRICITY?

A. By arranging a *series of metal plates* in a pile, placing them in pairs, with a *wet cloth* between them, it being necessary that one of each pair should be more *easily oxydised* than the other. The simple contact of these plates will produce a feeble and continued galvanic current.

Q. What is such an ARRANGEMENT of PLATES for producing electrical currents CALLED?

A. A *galvanic* or *voltaic battery.*

Q. Why are the terms "GALVANIC" and "VOLTAIC" applied?

A. They originated in honour of *Galvani* and *Volta*, the Italian philosophers who first developed the phenomena of chemical electricity, and the means of producing them.

Q. Are there MANY METALS, or other substances, which, when brought together, are capable of producing galvanic action?

A. The number is *large;* among them we may enumerate the following:—*zinc*, *lead*, *tin*, *antimony*, *iron*, *brass*, *copper*, *silver*, *gold*, *platinum*, *blacklead* or *graphite*, and *charcoal.*

Q. Will ANY TWO of these brought together produce a galvanic current?

A. They *will;* but they possess the power in *different degrees;* and the more remote they stand from each other in the order above given, the more decidedly will the chemical electricity be developed.

Thus zinc and lead will produce a voltaic battery, but it will be much less active than zinc and iron, or the same metal and copper, and this last less active than zinc and platinum, or zinc and charcoal.

Q. Does galvanic or voltaic electricity appear to consist of two kinds, POSITIVE and NEGATIVE, as in ordinary electricity?

A. It *does;* positive electricity always flows *from the metal which is acted upon* most powerfully, and negative electricity *from the other.*

Q. What do we mean when we speak of a GALVANIC CIRCUIT?

A. The connection of the two metals in the battery, so that the positive and negative electricities can *meet*, and *flow in opposite directions.*

Q. At what POINT in the circuit will the manifestations of electricity be most apparent?

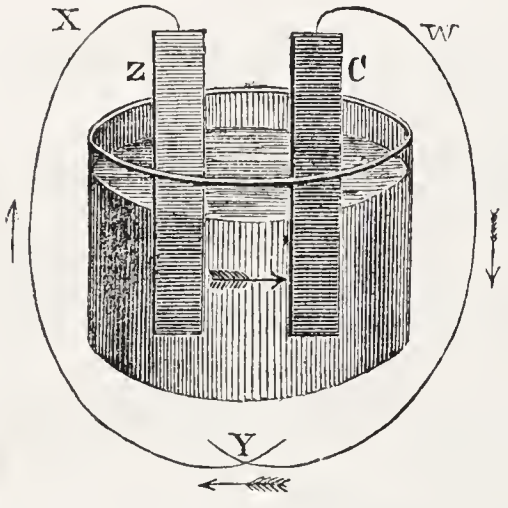
A. At the point where the *two currents meet.*

Q. What is meant by the POLES of the battery?

A. The two metals forming the elements of the battery are generally connected by copper wires; the *ends* of these wires, or the *terminal points* of any other connecting medium used, are called the poles of the battery.

Thus, when zinc and copper poles are used, the end of the wire conveying positive electricity from the zinc would be the positive pole, and the end of the wire conveying negative electricity from the copper plate would be the negative pole. Faraday describes the poles of the battery as the doors by which electricity enters into or passes out of the substance suffering decomposition.

Fig. 121.



A very simple, and at the same time an active, galvanic circuit may be formed by an arrangement as represented in fig. 121. C and Z are thin plates of copper and zinc immersed in a glass vessel containing a very weak solution of sulphuric acid and water. Metallic contact is made by means of the wires X and W soldered to the plates, the poles intersecting at Y. The current of positive electricity, when the circuit is closed, passes from the zinc, through the liquid, to the copper, and from the copper, along the conducting wires, to the zinc, as indicated by the arrows in the figure. A current of negative electricity traverses the circuit also, from the copper to the zinc, in a direction precisely reversed.

Q. Are two metals ABSOLUTELY ESSENTIAL to the formation of a simple galvanic circle?

A. No; a current is obtained from one metal and two liquids, provided the liquids are such that a *stronger chemical* action takes place on *one side* of the metal plate than on *the other.*

Q. Have galvanic batteries been formed WITHOUT resorting to the use of any metal?

A. *Dr. Baconio*, of Milan, constructed a voltaic pile entirely of *vegetable substances;* using discs of red beet-root, two inches in diameter, and similar discs of walnut-wood, the latter deprived of their resinous matter by maceration in a solution of cream of tartar in distilled vinegar.

With such a pile, using grass as a conductor, he is stated to have produced contractions of the muscles of a dead frog. Other experimentalists have formed voltaic piles wholly of animal substances.

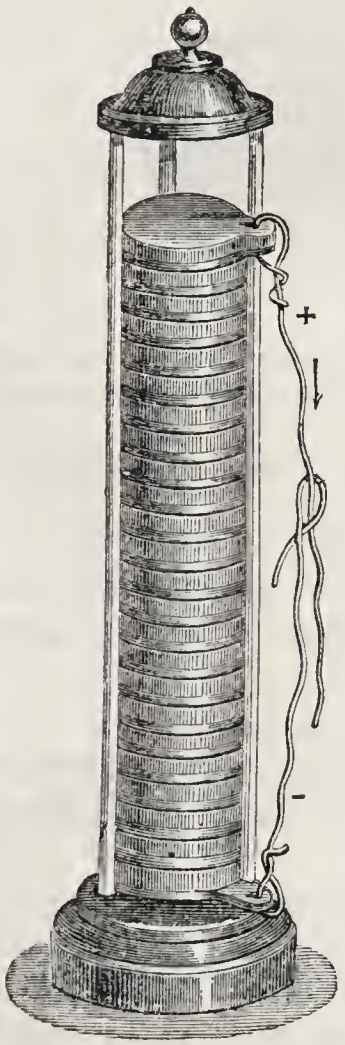
Q. By WHAT CHEMICAL ACTION can the greatest abundance of galvanic electricity be developed?

A. By the *oxidation of metallic zinc* by weak sulphuric acid.

Q. The electricity developed by the action of a single pair of plates immersed in acid water is very feeble: how can it be INCREASED?

A. By increasing the *number of the plates* and the *quantity of the liquid*, we increase the intensity of the electricity developed.

Fig. 122.



SECTION I.—PHENOMENA AND EFFECTS OF GALVANIC ELECTRICITY.

Q. What is the VOLTAIC PILE?

A. The term *pile* is generally applied to the apparatus which develops galvanic electricity. The voltaic pile takes its name from the inventor, Volta.

The voltaic pile consists of a series of plates piled one on the other, as seen in diagram 122. Thus, a copper disc or plate, a zinc disc, a piece of wet cloth; then upon a copper disc a zinc disc, and another piece of wet cloth; and so on throughout the whole extent of the pile.

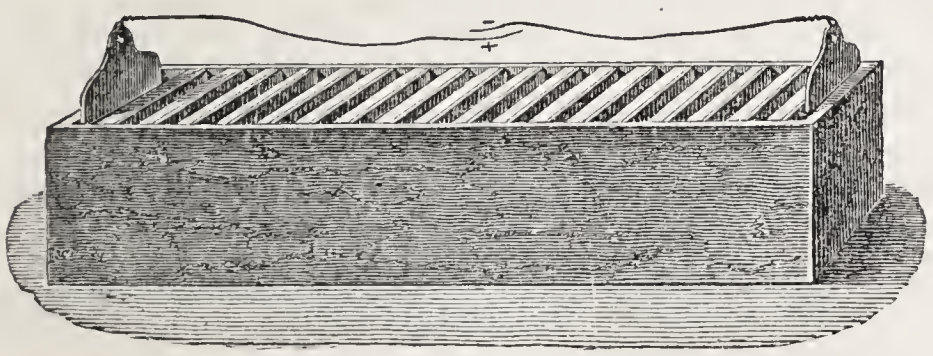
Q. What is the RESULT of such an ARRANGEMENT as that adopted in the VOLTAIC PILE?

A. Electrical action is excited and kept up.

Q. What OTHER SPECIES of GALVANIC PILES are used?

A. There are various modifications of the voltaic pile, but the principle of all is the same.

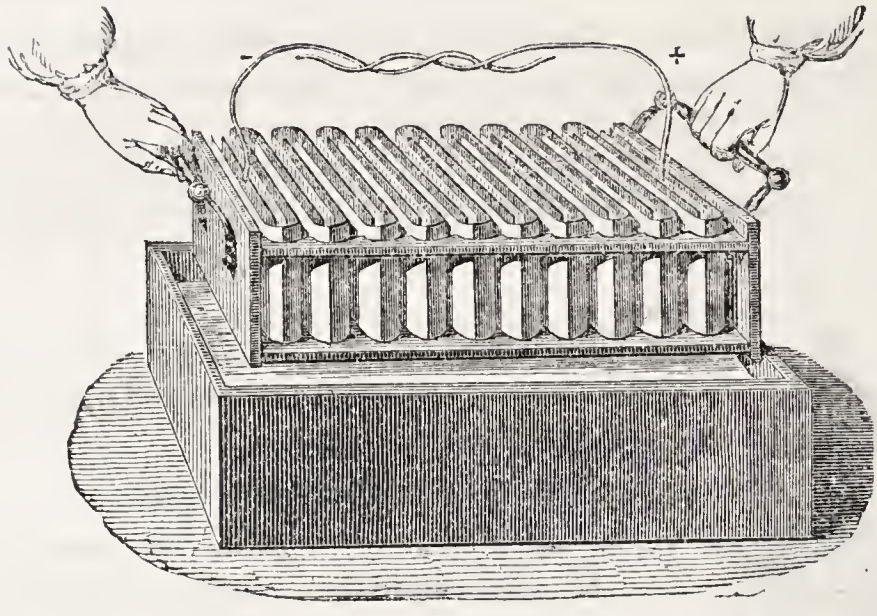
Fig. 123.



COMMON TROUGH PILE.

The trough pile (fig. 123) is the same as that of Volta, with the exception of its arrangement. It is formed of a long square box, lined with cement or mastic. The plates of zinc and copper are soldered together, and are then fixed in couples in the box, which is filled with a mixture of water and sulphuric acid.

Fig 124



In the pile seen in fig. 124. all the plates of zinc and copper dip into the same wooden trough, filled with sulphuric acid and water. This pile, which occupies but a small space, produces very powerful effects.

Q. What are the most ORDINARY EFFECTS produced by the developed electricity of a large galvanic battery?

A. The *production of sparks* and *brilliant flashes of light*, the heating and fusing of metals, the destruction of gunpowder and other inflammable substances, and the decomposition of water, saline compounds, and metallic oxides.

Q. How may the most SPLENDID ARTIFICIAL LIGHT known be produced?

A. By fixing pieces of *pointed charcoal* to the wires connected with opposite poles of a powerful galvanic battery, and bringing them into *contact.*

Q. How does this light appear to DIFFER from all other varieties of artificial light?

A. It appears to be *independent of combustion*, since the charcoal points appear to suffer no change, and the light is equally strong and brilliant in such gases as do not contain oxygen, and even under water, where all other artificial lights would be extinguished.

To produce the electricity which develops the light, zinc, or some other metal, must be oxidised, or burnt up, as much as oil in our lamps, or coal in the gas-retorts, for producing other species of artificial light.

Q. Can INTENSE HEAT be developed by the action of the galvanic battery, as well as intense light?

A. The *greatest artificial heat* man has yet succeeded in producing has been through the agency of the *galvanic battery.*

Q. Is HEAT EVOLVED whenever galvanic electricity is sent along a conducting body?

A. It *is;* bad conductors, however, of equal length and thickness, becoming much hotter than good ones in the same time.

Q. What REFRACTORY SUBSTANCES can be fused by the aid of the galvanic battery?

A. All the metals, including platinum, can be *readily melted;* quartz, sulphur, magnesia, slate, and lime are liquefied; and the diamond fuses, boils, and becomes converted into coal.

Q. When TWO different metals come into mutual contact, does the action which takes place between them favour chemical change?

A. It does in a *marked degree;* and it is to this action that we must ascribe many well-known phenomena, such as the more rapid oxidation or rust of certain metals when combined or in mere contact with other metals.

Thus, when sheets of zinc and copper immersed in dilute acid touch each other, the zinc oxidises or rusts more, and the copper less rapidly, than without contact.

Q. Why do IRON NAILS, if used in fastening copper sheathing to vessels, rust so much QUICKER than when in other situations, not in contact with copper?

A. Because the contact of the two metals excites *galvanic action*, which causes the iron to rust speedily, but protects the copper.

Q. How did Sir Humphrey Davy attempt to TAKE ADVANTAGE of this fact in protecting the copper sheathing of vessels?

A. Copper, when immersed in sea-water, *rapidly wastes* by the chemical action of the oxygen dissolved in sea-water; but if it be brought in contact with *zinc*, or some metal that is more electro-positive than itself, the zinc will undergo the *same change*, and the copper will be *preserved.* He therefore proposed to place at intervals over the copper small strips or wires of zinc or iron.

Q. How MUCH ZINC was required to protect a given surface of copper?

A. A piece of *zinc*, as large as a *pea*, was found adequate to preserve forty or fifty square inches of copper; and this wherever it was placed, whether at the top, bottom, or middle of the sheet, or under whatever form it was used.

Q. Was this plan found to WORK WELL practically, in preserving the sheathing of vessels?

A. It did *not:* the copper was protected at the *expense of the zinc;* but it was found, that unless a certain degree of corrosion took place in the copper, its surface became covered with sea-weeds and shell-fish, which impaired the speed of the vessel.

The corrosion or waste of the copper sheathing prevents these organisms from attaching themselves to its surface.

Q. Can GALVANIC ELECTRICITY be used in analysing or separating the constituents of bodies?

A. It is a powerful agent in *chemical analysis.* When transmitted through conducting fluids, it *separates them* into their constituent parts.

Q. Can WATER be decomposed by passing a current of galvanic electricity through it?

A. It *can;* hydrogen being given out at the positive pole of the battery, and oxygen at the negative pole.

Q. What LAW exists respecting the quantity of electricity necessary to decompose a compound substance?

A. The electricity which *decomposes*, and that which *is evolved* by the decomposition of a certain quantity of matter, are *alike.* Thus, water is composed of oxygen and hydrogen; now, if the electrical power which holds a grain of water in combination, or which causes a grain of oxygen and hydrogen to unite in the right proportions to

form water, could be collected and thrown into a voltaic current, it would be exactly the quantity required to produce the decomposition of a grain of water, or the liberation of its elements, oxygen and hydrogen.

Q. What GREAT CHEMICAL DISCOVERY was made by Sir Humphrey Davy through the decomposing powers of the galvanic battery?

A. The discovery that *potash*, *soda*, *lime*, *magnesia*, and other similar bodies, were *not simple* in their nature, as had been supposed, but compounds of a metal, with oxygen.

Q. What is ELECTROTYPING, or ELECTRO-METALLURGY?

A. It is the art or process of *depositing*, from a *metallic solution*, through the agency of galvanic electricity, a *coating* or *film* of metal upon some other substance.

Q. Upon what PRINCIPLES is it accomplished?

A. The process is based on the fact, that when a galvanic current is passed through a solution of some metal, as a solution of sulphate of copper (sulphuric acid and copper), *decomposition takes place;* the metal is separated in a metallic state, and attaches itself to the negative pole, or to any substance that may be attached to the negative pole; while the acid or other substance before in combination with the metal, goes to, and is deposited on the positive pole.

In this way a medal, a wood engraving, or a plaster cast, if attached to the negative pole, may be covered with a coating of copper; if the solution had been one containing silver or gold, the substance would have been covered with a coating of silver or gold, instead of copper.

Q. How can the THICKNESS of the deposits be REGULATED?

A. The thickness of the deposit, providing the supply of the metallic solution be kept constant, will depend on the *length of time the object is exposed to the influence of the battery.*

In this way, a coating of gold thinner than the thinnest gold-leaf can be laid on, or it may be made several inches in thickness, if desired.

Q. Explain MORE EXPLICITLY how the electrotype plate of the engraving is effected.

A. The engraved plate is *plunged into a solution of copper*, and the negative pole of the battery attached to it. The other pole of the battery is connected with the fluid solution. The solution is then decomposed; the copper resulting from it is deposited as a coherent mass, in a perfectly uniform manner, on the engraved plate, of which an exact copy *in relief* is obtained.

Q. What is meant by a copy IN RELIEF?

A. It is when the figure is formed by an *elevation*, and not by a *depression* of the surface. The lines constituting the figure map were cut into the plate in the original engraving; the deposit of copper filled up these depressions, and, when it was separated, the figure appeared to be raised on the surface.

Q. How, then, is an EXACT FAC SIMILE of the original plate obtained by the electrotype?

A. The electrotype itself is subjected to a repetition of the process, the result of which is that a reverse impression of it is obtained.

SECTION II.—THERMO-ELECTRICITY.

Q. What is THERMO-ELECTRICITY?

A. If a bar of metal is *warmed at one end*, and *kept cool* at the *other*, an electric current circulates through it, and may be carried off by connection with any good conductor. Electricity thus generated or developed is called "*thermo-electricity.*"

Q. What are its PROPERTIES?

A. The *same* as those of *common electricity.*

Q. What METALS are BEST suited for showing the effects of thermo-electricity?

A. *Bismuth* and *antimony.*

By binding two bars of these metals together at one end, an electric current can be proved to circulate at the slightest variation of temperature. It is by means of such an instrument that some of the most delicate researches upon heat have been effected.

Q. To WHAT may all the curious effects of electricity be ATTRIBUTED?

A. To an *effort of the power* or *force* to regain a position of *stability* when its equilibrium or balance has been disturbed. We have no evidence that electricity is an exciting power, but rather that it is one of those forces that tend to establish the balance of matter.

MAGNETISM.

CHAPTER XLI.

NATURAL MAGNETIC PHENOMENA.

Q. Is there any CONNECTION between MAGNETISM and ELECTRICITY?

A. There is every reason to believe that magnetism and electricity are but *modifications of one force.*

Q. What is a LOADSTONE or a NATURAL MAGNET?

A. It is an *ore of iron*, known as the "*protoxide of iron*," or "*magnetic oxide of iron*," which is capable of attracting other pieces of iron to itself; and if suspended freely by a thread, and left to take its own position, it will arrange itself so that its extremities will point towards the north and south poles of the earth.

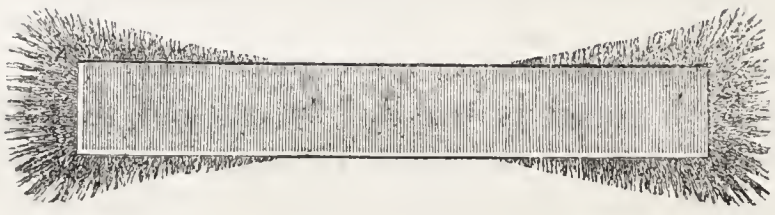
Q. What is the ORIGIN of the terms "magnet" and "magnetism?"

A. The loadstone, or natural magnet, was first found at *Magnesia*, in Lydia, Asia, whence were derived the names.

Q. What is the ATTRACTIVE INFLUENCE of the magnet called?

A. It is called magnetic power. Magnets do not possess the same magnetic force in every part.

Fig. 125.



If a magnetic bar be rolled in iron filings, they will be found to stick to the ends of the bar, as seen in the diagram. The centre does not possess the same attractive power as the extremities. When the attractive power is altogether imperceptible, it is called the NEUTRAL LINE.

Q. Can a NATURAL MAGNET COMMUNICATE its attractive properties to other bodies by contact?

A. It *can*, and that, too, without any *apparent loss* of attractive strength.

Q. What BODIES are capable of being magnetised by contact with natural magnets?

A. *Iron* and *steel* are the substances most susceptible of this influence, but brass, nickel, and cobalt can also become magnets.

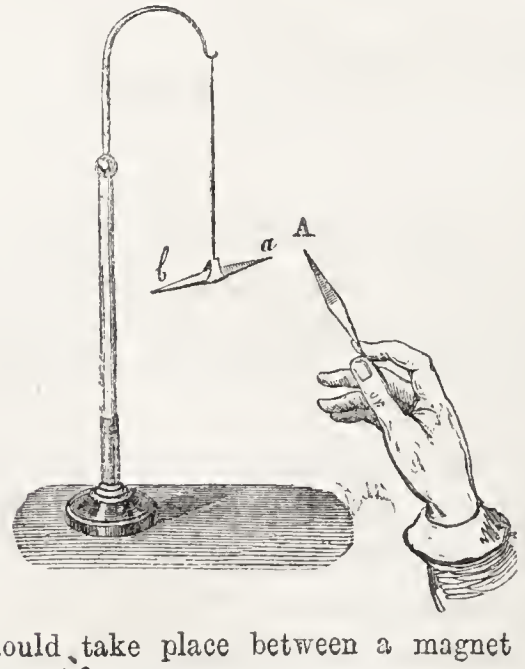
Q. Are there any OTHER substances besides metals that are magnetic, or can have magnetism imparted to them?

A. This property is *not confined to the metals:* the emerald, the ruby, and various precious stones, as well as glass, chalk, bone, and wood, are more or less susceptible to the magnetic influence; and recent experiments would seem to show that the influence of magnetism is as pervading and wide extended as that of electricity.

Q. What is MEANT by magnetic polarity?

A. Two bodies endowed with the property of magnetism will *attract each other* at one part of their dimensions, and *repel* each other at *another* part. These contrary effects, belonging to opposite sides or ends, are called *magnetic polarity.*

Fig. 126.



If we hang a magnetised needle, as seen in the figure, *a b*, by a fine thread, and bring the south pole, A, of another magnet near the south pole *a* of the first magnet, we shall see a marked repulsion; if, on the other hand, we present the pole A to the north pole *b* of the suspended magnet, there will be a very observable attraction. We learn from this that the same poles in two different magnets repel each other, and that the opposite poles attract.

Q. Does the magnetism imparted to a piece of SOFT IRON, or steel, by contact with a natural magnet, remain permanent in their substances?

A. In the *steel* it *does*, but the soft iron *loses its power* as soon as it is removed from the magnet.

Q. Is it necessary that ABSOLUTE CONTACT should take place between a magnet and a piece of soft iron to render the latter a magnet?

A. No; every piece of soft iron brought *near* a magnet becomes, by induction, itself a magnet.

Q. What do you mean by INDUCTION?

A. It is the production of *like effects* in *bodies near to one another.* In electricity or magnetism it is the influence exerted by an electrified or magnetised body through a non-conducting medium, without any apparent communication of a current.

Q. What is meant by the DIRECTIVE POWER of the magnet?

A. It is that power which will cause a magnet, when suspended freely, to constantly *turn the same part* towards the north pole, and the opposite part towards the south pole of the earth.

Q. What are the POLES of a magnet?

A. They are the *ends* of the magnet, and are denominated north and south poles, according as they point to the north or south poles of the earth.

Q. When is a magnet said to TRAVERSE?

A. When it places itself *freely in a north and south line.*

Q. What are the POLES of the earth?

A. The *extremities of the earth's axis*, or the points on the surface of the globe through which the axis passes.

Q. Under what CIRCUMSTANCES do the north and south poles of two magnets ATTRACT and REPEL each other?

A. The north or the south poles of the magnets *repel each other*, but the north pole of the *one* will *attract* the south pole of *the other.*

Q. What is a MAGNETIC NEEDLE?

A. Simply a *bar of steel* which is a *magnet*, suspended in such a way that it can *freely turn* to the north or south.

Fig. 127.

A MARINER'S NEEDLE.

Q. What is the SIMPLEST WAY of constructing a magnetic needle?

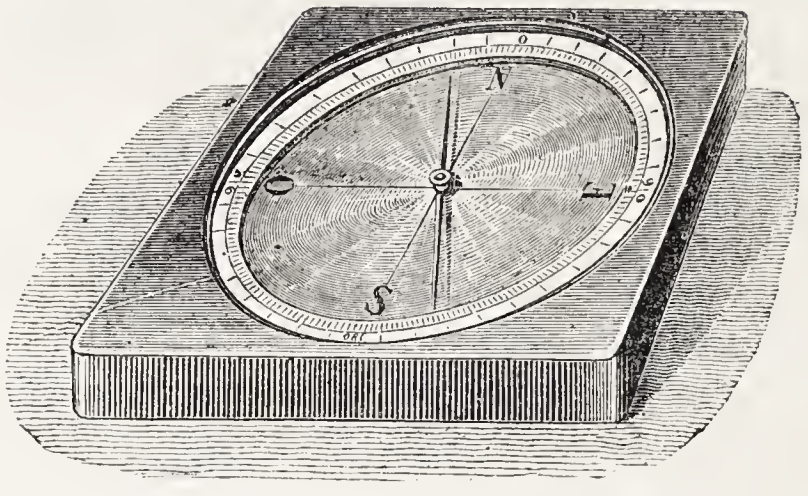
A. If we place a magnet on a *piece of cork*, and allow it to float freely *in water*, with no iron near it, it places itself in the magnetic meridian.

Q. What is a MARINER'S COMPASS?

A. It is a *delicate steel bar or needle* balanced upon a *pivot* placed beneath its centre of gravity in such a way that it can turn without obstruction. (*See fig.* 127.) This needle is usually enclosed in a

box, upon the bottom of which is a card, with the various points—north south, east, west, &c. &c., marked upon it. (*See fig.* 128.)

Fig. 128.



Such a needle, if the box containing it be placed on a level surface, will generally be observed to vibrate more or less, till it settles in such a direction that one of its extremities or poles will point towards the north, and the other, consequently, towards the south. If the position of the box be altered or reversed, the needle will always turn and vibrate again, till its poles have attained the same directions as before.

Q. Does the compass needle always point EXACTLY north and south?

A. It does *not;* its natural direction is towards northern and southern parts, but it seldom points due north or south.

Q. What is the VARIATION OR DECLINATION of the needle?

A. The *deviation* from the *true* north and south.

Q. Are there any points upon the earth's surface where the needle does NOT VARY, but points to the TRUE NORTH?

A. There are *two lines* upon the surface of the globe, along which here is *no variation*, called the eastern and western line.

Q. Are these lines REGULAR?

A. They are very *irregular*, showing that the powers on which terrestrial magnetism depends are regulated by causes which science has not yet reached.

Q. Where is the WESTERN LINE of no variation?

A. It begins to the *west of Hudson's Bay*, passes in a *south direction* through the American lakes to the West Indies and the extreme *eastern point of South America.*

Q. Where is the EASTERN LINE of no variation?

A. It begins on the *north* in the *White Sea*, makes a great semicircle, descending south, until it reaches the latitude of 71°; it then passes along the *Sea of Japan*, and goes westward across *China and Hindostan to Bombay;* it then bends east, touches *Australia*, and goes south.

Q. If, instead of balancing the magnetic needle on a pivot beneath centre of gravity, we cause it to be SUSPENDED from its centre and carefully balanced, in what direction will it turn?

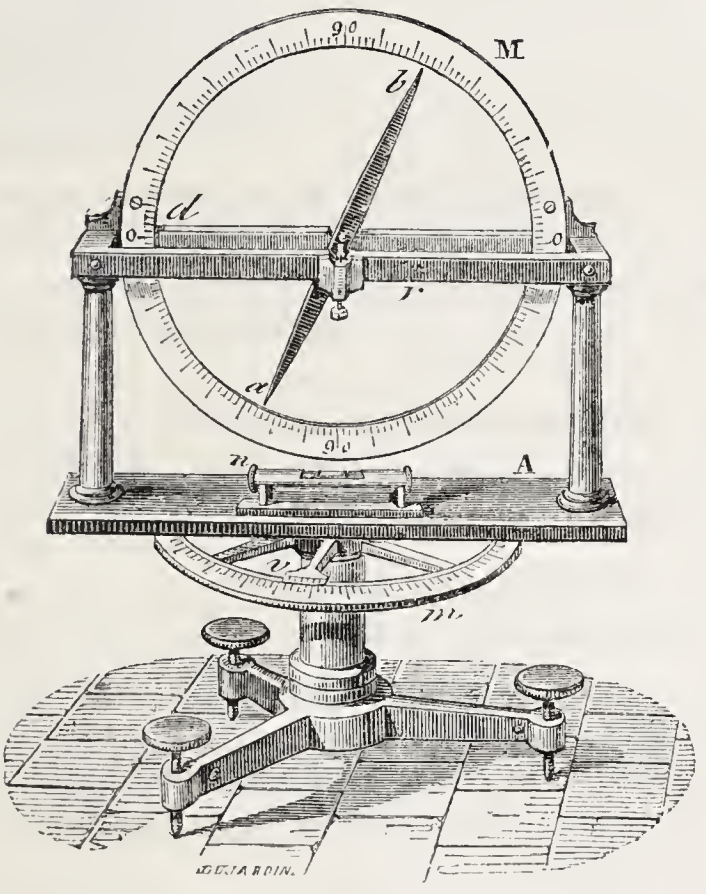
A. If a simple bar of steel or ordinary needle were suspended from its centre as above described, it would *hang horizontally*, and show no inclination to *dip* from a horizontal line, either on one side or the other of the centre of suspension. But if the bar or needle be made a magnet, it will no longer lie in a horizontal direction, but one pole will incline downwards and the other upwards; the inclination in this latitude to the horizon being about 70°.

Q. What is such a needle CALLED ?

A. A *dipping needle.*

The construction of the dipping needle is represented by fig. 129.

Fig. 129.



Q. As the ordinary compass does not point directly to the north or south pole of the earth, but to a point a little removed from them, what NAME has been given to these points ?

A. The *magnetic poles* of the earth.

Q. Is the EXACT POSITION of these places known ?

A. The position of *one* of these poles in the northern hemisphere is known, having been discovered and visited by *Capt. Ross* when attempting to discover the north-west passage around the continent of America. The exact position of the southern magnetic pole is not known.

Q. If the ordinary compass be carried to this point, in WHAT MANNER is it affected?

A. It appears to *lose its power*, and points indifferently in any direction.

Q. In WHAT MANNER would the dipping needle be affected if placed at the magnetic pole?

A. It would *cease to dip*, and stand *perfectly upright.*

Q. What POSITION does the dipping needle assume at the equator?

A. It remains *perfectly horizontal;* as we go north or south, however, it dips more and more, until at the magnetic poles it is perpendicular,—the end which was uppermost at the north being the lowest at the south.

Q. If the magnetic needle is thus subject to variations, how can it be RELIED UPON?

A. The variations of the needle, except in the vicinity of the poles, are *not sufficient* to affect its *general accuracy*, and for all the ordinary purposes of the wanderer upon the ocean, the desert, or the wilderness, it may be considered as free from error; for more accurate purposes it is necessary to apply a rule of corrections.

Q. WHO FIRST DISCOVERED the fact that a magnet would invariably point to the north and the south, and made use of this knowledge in constructing a compass?

A. It is claimed to have been discovered by the *Chinese:* it was known in Europe, and used in the Mediterranean, in the thirteenth century.

Q. How were the COMPASSES of that time constructed?

A. They were merely *pieces of loadstone* fixed to a *cork*, which floated on the surface of water.

Q. Is the EARTH itself supposed to be a MAGNET?

A. It is undoubtedly a *great magnet.*

Q. Is IRON, under certain circumstances, rendered MAGNETIC by the inductive action of the earth's magnetism?

A. Most *iron bars* and *rails*, as the vertical bars of windows, that have stood for a considerable time in a perpendicular position, will be found to be *magnetic.*

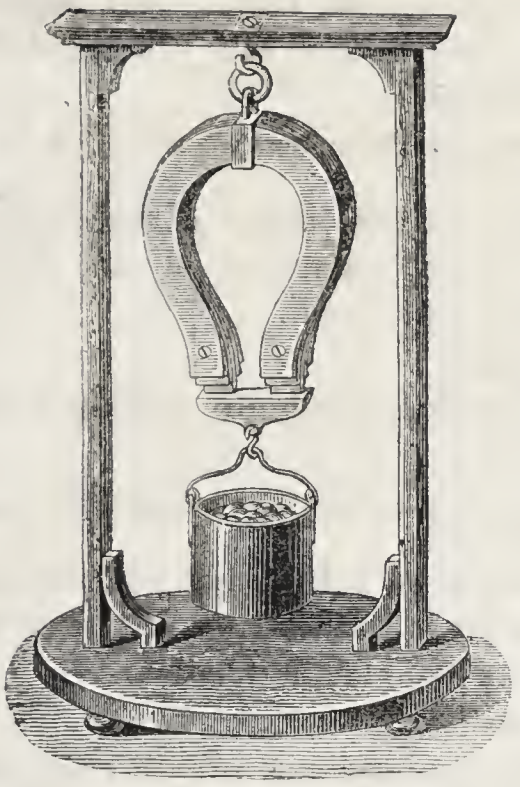
Q. If we suspend a bar of soft iron sufficiently long in the air, will it assume MAGNETIC PROPERTIES?

A. It *will* gradually *become magnetic;* and although when it is first suspended it points indifferently in any direction, it will at last point *north and south.*

Q. How may a bar of iron, such as a kitchen poker, be made IMMEDIATELY MAGNETIC, without resorting to the use of other magnets?

A. If the bar devoid of magnetism is placed with *one end on the ground*, slightly inclined towards the north, and then struck one *smart blow* with a *hammer* upon the upper end, it will immediately acquire *polarity*, and exhibit the attractive and repellant properties of a magnet.

Fig. 130.



Q. What is a HORSE-SHOE MAGNET?

A. It is a *magnetic bar*, bent into the *form of a horse-shoe.*

When a piece of iron, not magnetic, is brought in contact with a common magnet, it will be attracted by either pole; but the most powerful attraction takes place when both poles can be applied to the surface of the piece of iron at once. It is on this account that artificial magnets are often bent into the form of a horse-shoe, the north pole being usually marked by a line or point to distinguish it. Very powerful horse-shoe magnets are made by binding a number of magnetised bars together with a piece of soft iron, so as to form a compound horse-shoe, as is seen in fig. 130.

Q. If we BREAK a magnet across the middle, what HAPPENS?

A. Each fragment becomes converted into a *perfect magnet;* the part which originally had a north pole acquires a south pole at the fractured end, and the part which originally had a south pole gets a north pole.

Q. If we divide up a magnet to the extreme degree of mechanical fineness possible, will the pieces possess MAGNETIC POWERS?

A. Each fragment, however small, will be a *perfect magnet.*

Q. Are the properties of the magnet at all AFFECTED by the presence or absence of air?

A. They are *not;* its influence is as great in a vacuum (empty space) as in any other situation.

Q. What EFFECT has HEAT upon the power of a magnet?

A. It *weakens it;* and a *white heat destroys it.*

Q. How is the POWER of a magnet STRENGTHENED?

A. The gradual *addition of weight* to a magnet, kept in its proper situation, increases the magnetic power.

Q. In what POSITION should magnets be kept?

A. Magnets should always be kept with their *poles pointing to the poles of the earth:* this is said to be their proper position.

Q. Can two or more magnets communicate to IRON a power GREATER than either of them possesses singly?

A. Two or more magnets joined together may communicate a *greater power* to iron or steel than *either of them possesses singly.*

Q. When an iron bar is rendered magnetic, where does the power appear to RESIDE in it?

A. It appears to reside on the *surface*, and to circulate about it.

We are led to this belief from the circumstance of a stronger power, in proportion, being produced in thin plates of steel than in thick ones; and from the acquired magnetism being diminished by rust, filing, or grinding, it appears that the virtue communicated is more external than internal.

Q. How great a SUSTAINING POWER can magnets exert?

A. The lifting or sustaining power of magnets varies very materially. The most powerful that we are acquainted with are capable of sustaining *twenty-six times their own weight.*

Q. WHO first noticed the VARIATION of the magnetic needle from the true north and south?

A. It was first noticed by *Columbus* in his first voyage of discovery. It was also observed by the sailors, who were alarmed at the fact, and urged it as a reason why they should turn back.

Q. Are the magnetic poles of the earth STATIONARY?

A. They are *not*, but change their position gradually during long intervals of time.

Q. What curious fact has been noticed in regard to the CONNECTION between the magnetic poles of the earth and the points of GREATEST COLD?

A. The points where the greatest degree of cold is experienced, or where the yearly mean of the thermometer is lowest upon the surface of the earth, *coincides* with the *location of the magnetic poles.*

Q. Is the magnetic needle subject to a DAILY variation?

A. It *is:* this movement or variation commences about *seven* in the morning, when the north end of the needle begins to deviate towards the west; it reaches its greatest deviation about two o'clock in the afternoon, when it begins to return slowly to its original position.

Q. Besides this daily variation, is the needle subject to OTHER VARIABLE MOVEMENTS?

A. It has *a yearly movement;* and a movement different in the winter months from that noticed in the summer months.

Q. What is supposed to be the OCCASION of these daily, monthly, and yearly variations of the magnetic needle?

A. *Variations of temperature*, depending upon changes in the position and course of the sun.

Q. Does the AURORA BOREALIS have an effect upon the magnetic needle?

A. It *does* very sensibly, causing it to *tremble* and deviate from point to point.

Q. Do the RAYS of LIGHT have the power of exciting magnetism?

A. Light is generally believed to have the power of *inducing magnetism in steel.* Sewing-needles, it is said, when exposed to violet-coloured light, or when covered with a blue glass, become magnetic.

Q. Into what TWO GREAT CLASSES, according to the latest experimental researches, are all bodies divided as respects magnetic influences?

A. Into *magnetic* and *diamagnetic* bodies.

Q. What is meant when we call a body DIAMAGNETIC?

A. The magnetic power is found to influence all bodies in two different ways; one class of substances act in relation to magnetism like iron, and arrange themselves along the line of magnetic force: these are called magnetic bodies. Another set, of which the metal

bismuth may be taken as a representative, always place themselves at *right angles* to this line: these are called *diamagnetic bodies.*

Q. How do magnetic and diamagnetic bodies DIFFER as regards ATTRACTION and REPULSION?

A. The magnetic body is *attracted* by *each pole;* the diamagnetic body is equally *repelled by either pole.* Magnetism may be regarded as an attractive force, diamagnetism as a repelling one.

Every substance in nature is in one or the other of these conditions. "It is a curious sight," says Dr. Faraday, "to see a piece of wood, or of beef, or an apple, or a bottle of water repelled by a magnet; or taking the leaf of a tree, and hanging it up between the poles, to observe it take an equatorial position."

Q. To WHAT FORCE have some attributed the turning of the sunflower to the sun, the closing of the convolvuli, and the directions of spirals formed by twining plants?

A. To the *diamagnetic* property, which all plants have been found to possess. This idea is, however, a speculative one.

Q. Have GASES been ascertained to be influenced by the magnetic power?

A. *Oxygen* is strikingly magnetic; *nitrogen* is singularly the contrary. These two gases form our atmosphere; and both possessing different properties, the result, when united, is a compound, neutral in all its relations to matter.

CHAPTER XLII.

ELECTRO-MAGNETISM.

Q. What is ELECTRO-MAGNETISM?

A. It is the magnetism developed through the agency of *electrical* or *galvanic action.*

Q. What were the EARLIEST PHENOMENA observed which indicated a relation between magnetism and electricity?

A. It was noticed that *ships' compasses* have their directive powers impaired by lightning, and that sewing needles could be rendered magnetic by electric discharges passed through them.

Q. What DISCOVERY, made by Professor Oersted of Copenhagen, established beyond doubt the connection of electricity and magnetism?

A. He ascertained that a magnetic needle placed near a metallic wire connecting the poles of a galvanic battery was compelled to change its direction, and that the new direction it assumed was determined by its position in *relation to the wire* and to the direction of the current *transmitted along the wire.*

Q. What OTHER IMPORTANT DISCOVERY was made about the same time?

A. It was found that if a bar of soft iron, not possessing magnetic power sufficient to elevate a grain weight, be placed within a coil of copper wire through which a galvanic current is passing, it will

become through the influence of the current a *powerful magnet;* and will, so long as the current flows, sustain weights amounting to many hundreds of pounds.

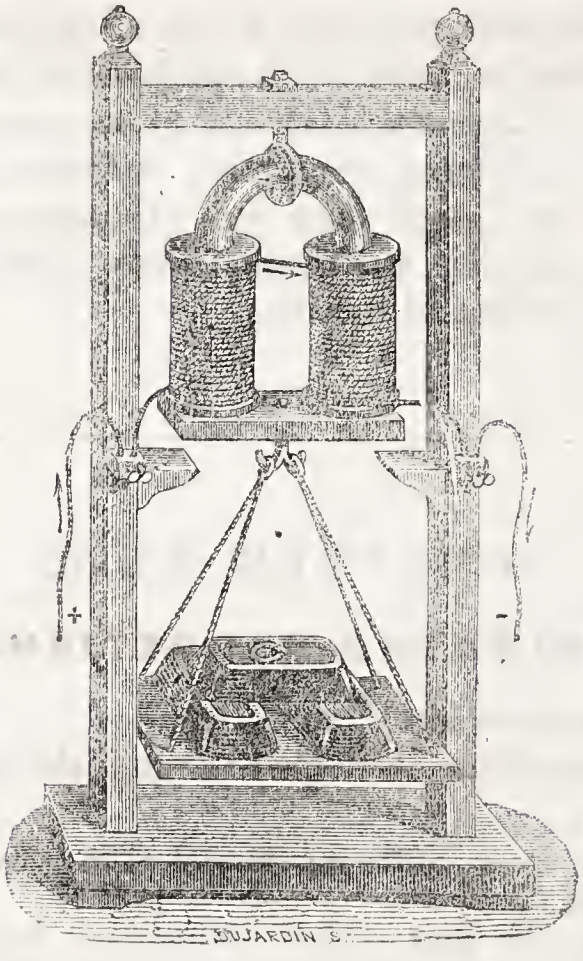
Q. Is the magnetic power of the bar found to be WHOLLY DEPENDENT on the existence of the current?

A. It *is;* the moment the current stops, the weights *fall away* from the bar in obedience to the law of gravity.

Q. How GREAT WEIGHTS have been lifted by magnets formed in this manner?

A. An electro-magnet constructed by Professor Henry was capable of elevating and sustaining about a *ton weight.* (*See fig.* 131.)

Fig. 131



Q. What OTHER EXPERIMENTS have been made in the science of electro-magnetism?

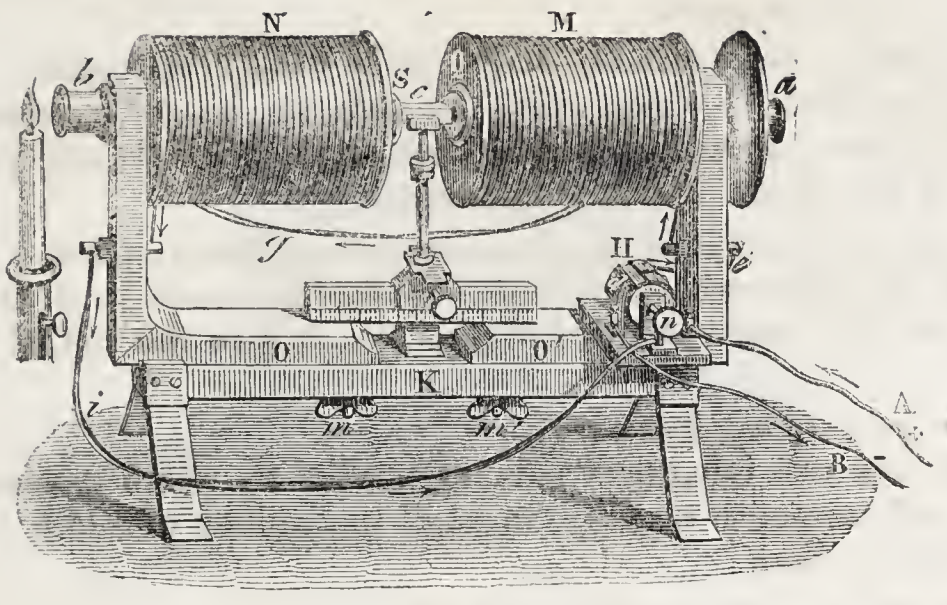
A. Professor Moll, of Utrecht, with a battery presenting a zinc surface of *eleven square feet*, caused the magnet to lift *seventy-five pounds.*

Q. Are an OPTICAL EFFECTS produced by electro-magnetism?

A. Yes; Professor Faraday discovered that a strong electro-magnet had such a powerful effect on some transparent substances, that a *polarised ray of light* passing through them in the direction of the magnetic poles, the *plane of polarisation*, underwent a change, according to the direction of the magnetic influence.

In figure 132 is shown the apparatus employed by Professor Faraday to obtain the results mentioned. It is formed of two electro-magnets, M and N, fixed to two iron

Fig. 132.



slides, O and O', sliding on a support, K. The electric current of a battery enters at A, passes along to a cylinder H, thence to the bobbin, M ; so along the wire *g* to N, descends to *i*, reaches the cylinder H, and goes out at B. The iron cylinders, S and Q, are pierced with holes, to allow the light to pass through. At *b* and *a* are two prisms, the former acting as a polariser, the latter as an analyser ; thus the prism *a* completely extinguishes the light which passes through the prism *b*, as long as the electric current does not pass ; but directly the communication is established, the light appears ; and whichever way we turn the analyser, *a*, it still exhibits the various colours of the spectrum. This shows us the effects which are produced upon light by electro-magnetism.

Q. Has this enormous force, developed and destroyed in an instant by making or breaking the current, been employed for any PRACTICAL PURPOSE ?

A. The attempt has often been made to take advantage of it for *propelling machinery*, but thus far all efforts have failed to produce any practical result.

Q. What is the REASON why this enormous power cannot be used with advantage ?

A. Because the rate at which the power diminishes as we recede from the contact point of the magnets prevents our obtaining the *full force* of the magnets. Thus, a magnet whose force in contact would be sufficient to raise 250 pounds, would exert a force of only 90 pounds at the distance of $\frac{1}{100}$th of an inch, and of only 40 pounds at the distance of $\frac{1}{50}$th of an inch.

Q. What OTHER DIFFICULTY has presented itself ?

A. It is found that, notwithstanding the loss of power with distance, a still *greater loss takes place with motion.* The moment any magnetic body is moved in front of either a permanent or an electro-magnet it loses power, and this loss increases very rapidly with the increase of velocity.

Q. Have GREAT EFFORTS been made to overcome these difficulties ?

A. Professor Jacobi, under the direction of the Russian government, expended upwards of £30,000, and then *abandoned* the enterprise as *impracticable.*

Q. Can a SPARK be obtained from an electro-magnet as from an electrical machine or galvanic battery ?

A. *Heat and light*, by proper arrangements, can both be obtained from the electro-magnet.

Q. Can CONSTANT and POWERFUL electro-currents be obtained from magnets?

A. A *combination of horse-shoe magnets* can be so arranged, that by causing them to revolve near to each other, a steady and powerful current of electricity can be generated.

Q. By WHAT INFLUENCE is it supposed that the earth is rendered magnetic?

A. By the influence of *currents* circulating about it, in the same manner as they circulate around the iron bar in the coil of copper wire.

Q. What is the ELECTRIC TELEGRAPH?

A. The electric telegraph is an apparatus by which messages can be sent with immense rapidity, through the agency of *voltaic currents along metallic wires.*

Q. How LONG have such telegraphs been in USE?

A. In 1814 M. Sœmmeny invented a telegraph based on the *electrical* theory; but the telegraph could not be made simple enough till Professor Wheatstone introduced the use of *electro-magnets.*

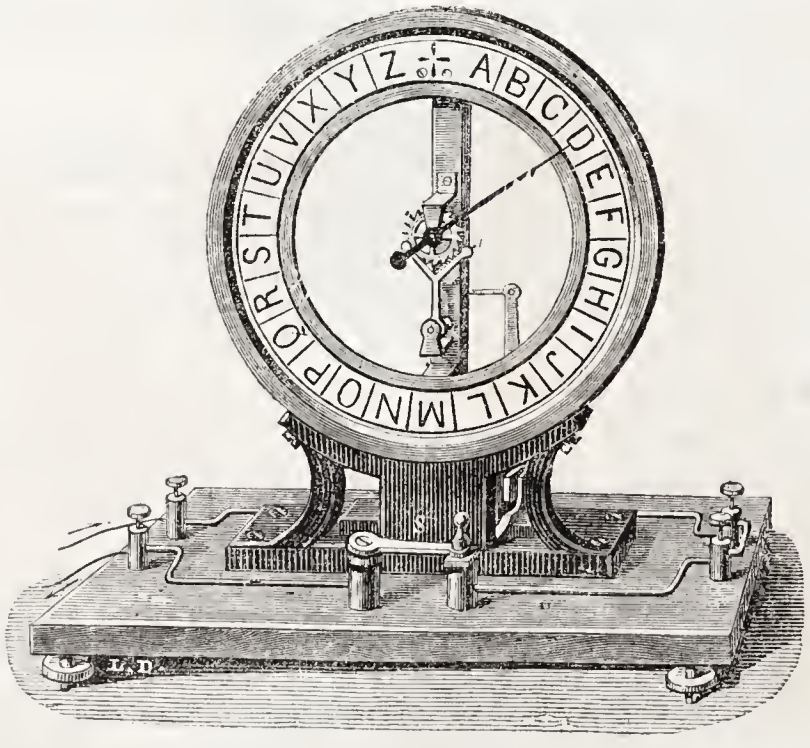
Q. What VARIETIES of the electric telegraph are used?

A. The principle in all is the same; the *form* only is varied.

Q. How MANY DIFFERENT FORMS are there?

A. We may mention three: the *dial telegraph*, the *signal telegraph*, and the *writing telegraph.*

Fig. 133.

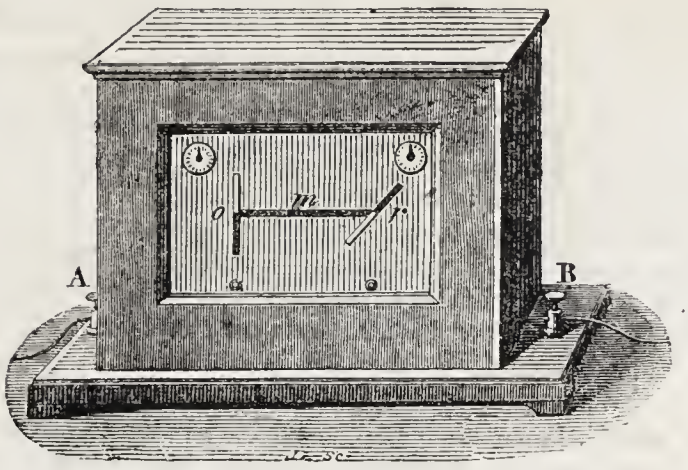


THE DIAL PLATE OF AN ELECTRIC TELEGRAPH.

Two dial plates are employed; one at the office from which the message is sent, one at the office at which the message arrives. The needle, or index, is moved by the hand of the operator to the different letters inscribed on the dial, until the word, or words, to

be transmitted are spelt. The electric current moves the hand on the dial at the other office in exactly the same way, so that the word, or words, are spelt there also; and thus a message is conveyed.

Fig. 134.



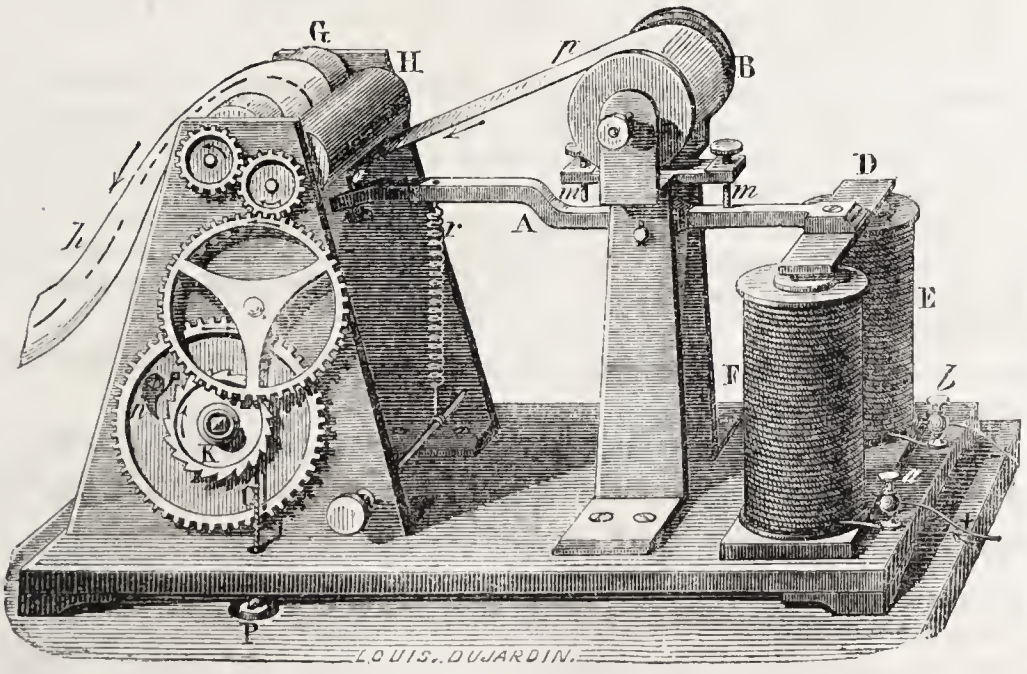
THE RECEIVER OF A SIGNAL TELEGRAPH.

The engraving shows the front of a box on which is placed a white plate, with a black line, *m*, having at its two ends movable radii *o*, *r*. The different angles assumed by these, in all forty-nine, convey different signals, previously arranged and understood. The motion of the indicators is produced by clock-work, and an electric magnet in connection with the wire A B, which extends from station to station, and conveys the electric current.

Q. Upon WHAT PRINCIPLE does the construction of the writing magnetic telegraph depend?

A. Upon the principle that a current of *electricity* circulating about a bar of soft iron is capable of *rendering it a magnet.*

Fig. 135.



The arrangement by which this principle is made available in the construction and operation of this magnetic telegraph will be understood by reference to the accompanying diagram (fig. 135), which represents the construction and arrangement of this form of telegraph. F and E are pieces of soft iron, surrounded by coils of wire, which are connected at *a* and *b* with wires proceeding from a galvanic battery. When a current is transmitted from a battery located one, two, or three hundred miles, as the case may be

it passes along the wires and into the coils surrounding the pieces of soft iron, F and E, thereby converting them into magnets. Above these pieces of soft iron is a metallic bar or lever, A, supported on its centre, and having at one end the arm D, and at the other a small steel point, *o*. A ribbon of paper, *p h*, rolled on the cylinder, B, is drawn slowly and steadily off by a train of clock-work, K, moved by the action of the weight, P, on the cord, C. This clock-work gives motion to two metal rollers, G and H, between which the ribbon of paper passes, and which, turning in opposite directions, draw the paper from the cylinder, B. The roller, H, has a groove around its circumference (not represented in the engraving), above which the paper passes. The steel point, *o*, of the lever, A, is also directly opposite this groove. The spring, *r*, prevents the point from resting upon the paper when the telegraph is not in operation.

The manner in which intelligence is communicated by these arrangements is as follows: The pieces of soft iron F and E, being rendered magnetic by the passage of a current of electricity transmitted from the battery through the coils of wire surrounding them, attract the metal arm D of the lever A. The end of the lever at D being depressed, the steel point *o* at the other extremity is elevated and caused to press against the paper ribbon and indent it. When the current from the battery is broken or interrupted, the pieces of soft iron F and E, being no longer magnetic, cease to attract the arm D. The lever A is therefore drawn back to its former position by the action of the spring *r*, and the steel point *o* ceases to indent the paper. In this way marks of any length can be made, and by a series or combination of dots and marks intelligence is communicated.

Q. Upon WHAT PRINCIPLE is the chemical telegraph, commonly known as Bain's, constructed?

A. In this there is *no magnet created*, but a small steel wire, connected with the wire from the line, presses upon the roll of paper moved by clockwork. This paper, before being coiled on the roller, has been dipped in a nearly colourless chemical solution, but which becomes coloured when an electric current passes through it.

By sending a current through the wire resting on the paper, we can stain it, as it were, in dots and lines in the same manner as the last instrument embossed it in dots and lines.

Q. What was the METHOD first proposed for COMMUNICATING INTELLIGENCE by electricity?

A. By *turning a compass needle* by causing a current of electricity to pass along its length.

The manner in which this turning of the needle would serve to communicate intelligence would be as follows:—If at a given point we place a galvanic battery, and at a hundred miles from it there is fixed a compass needle, between a wire brought from, and another returning to the battery, the needle will remain true to its polar direction so long as the wires are free from the excited battery; but the moment connection is made, the electricity of the whole extent of wire is disturbed, and the needle is thrown at right angles to the direction of the current. The motion of the needle may thus be made to convey intelligence.

Q. Why is it necessary, in conveying the telegraph wires, to SUPPORT them upon GLASS or EARTHEN cylinders?

A. These are used for the purpose of insuring the perfect *insulation* of the wires, since but for this the electricity would pass down a damp pole to the earth, and be lost.

Q. Is there any TRUTH in the idea that many persons have, that some PRINCIPLE passes along the telegraphic wires when intelligence is transmitted?

A. This supposition is *wholly erroneous;* the word current, as something flowing, conveys a false idea, but we have no other term to express electrical progression.

Q. How can we gain an idea of what really takes place, and of the NATURE of the INFLUENCE transmitted?

A. The earth and all matter are *reservoirs of electricity;* if we

disturb this electricity at London by voltaic influence, its pulsations may be felt in York. Suppose the telegraphic wire were a tube, extending from London to York, filled with water. Now, if one drop more is forced into it at London, a drop must fall out at York, but no drop was caused to pass from London to York. Something similar to this occurs in the transmission of electricity.

Formerly two wires were required in telegraphing: one conveyed the current from the battery to the electro-magnet at a distance through which it passed, and then returned by another wire back to the battery. Now but one wire is used. It was found that the earth itself might be made to perform the function of the returning wire. All that is necessary is that one short wire from the galvanic battery at one end of a line, and from the electro-magnet at the other end, should be sunk into the moist earth, and there connected with a mass of conducting metal, from which the electricity passes to complete the closed circuit.

Q. Can electricity be employed for MEASURING TIME?

A. It *can;* and by its agency a great number of *clocks* can be kept in a state of *uniform correctness*, which no other arrangement can effect.

Q. How is this ACCOMPLISHED?

A. A battery being united with the chief clock, which is itself connected by wires with any number of clocks arranged at a distance from each other, has the current continually and *regularly interrupted by the beating of the pendulum*, which interruption is experienced by all the clocks included in the electric circuit; and, in accordance with this making and breaking of contact, the indicators or hands move over the dial at a constantly uniform rate.

CHEMISTRY.

CHAPTER XLIII.

CHEMICAL FORCES AND AGENCIES.

Q. Are all MATERIAL FORMS on the earth the result of CHEMICAL combination?

A. They are; and the chief object of the science of chemistry is to ascertain the composition of substances, and to determine the laws by which they are governed.

Q. What do we understand by CHEMICAL PROCESSES and CHEMICAL ACTION?

A. Such processes or action by which the weight, the form, the solidity, the colour, the taste, the smell, and the influence of substances *become changed*, so that new bodies with quite different properties are formed from the old.

Q. Are chemical processes and action CONTINUALLY GOING ON in the bodies and systems of all animals and plants?

A. Yes; but so long as the animal or plant is endowed with *life*, the chemical forces are *controlled by a higher power*, which we call *vital force.*

Q. When an ANIMAL OR PLANT DIES, what becomes of these two forces?

A. The vital force *ceases to exist*, and the chemical forces, gaining the mastery, reduce all the component parts of the former living structure to their ultimate elements. "Earth returns to earth, dust to dust."

Q. Into what TWO great CLASSES may all substances be divided?

A. Into *simple* and *compound substances.*

Q. What is a SIMPLE SUBSTANCE?

A. A body which cannot be *divided*, *analysed*, or *decomposed*, is called a simple substance or element: gold, silver, iron, oxygen, hydrogen, and nitrogen are considered simple substances or elements, because we are unable to decompose them, convert them into, or create them from, other bodies.

Q. What is a COMPOUND substance?

A. One that can be *divided*, *decomposed*, or *converted* into other substances: air is a compound body, because it is composed of oxygen and nitrogen.

Q. With HOW MANY simple substances or elements are we acquainted?

A. The number now known to exist is *sixty-four.*

Q. Are these substances EQUALLY DISTRIBUTED over the surface of the earth?

A. They are *not;* most of them are *exceedingly rare*, and some ten or twelve only make up the great bulk and mass of all the objects we see around us.

Q. The elementary bodies by uniting form compounds: into what TWO great CLASSES may all the compounds of matter be divided?

A. Into *organic* and *inorganic* substances.

Q. Can all the ELEMENTS take part in forming organic and inorganic bodies?

A. *All* of them are capable of entering into inorganic combinations, but only a *few* are capable of forming organic compounds.

Q. What is an INORGANIC substance?

A. An inorganic substance is a product of the so-called *inanimate world*—a substance which is destitute not only of life, but of any organisation or properties derived either directly or indirectly through the agency of the vital force.

A crystal has a regular form and symmetry, and may present a beautiful and complex arrangement of parts; but this complexity of arrangement was not produced through any vital agency, neither were the particles of which it is composed ever endowed with life. Most of the inorganic substances which occur in nature may be artificially imitated by combining together the materials of which they are composed.

Q. What is an ORGANIC substance?

A. An organic substance or compound is one which has *originated*

or been produced through the *agency of life*, or the instrumentality of the vital force.

The distinctive characteristic of inorganic bodies is rest; the distinctive trait of organised bodies is motion, *life*. A rock or crystal once formed, and left undisturbed by foreign influences, never changes. An organic body, on the contrary, is limited in its duration, and will ultimately decompose, change, die, and its elementary constituents assume new and varied forms.

Q. Can we make ARTIFICIALLY an ORGANIC body?

A. *Strictly speaking, we cannot;* chemistry has, however, in certain cases, succeeded in forming certain compounds artificially, which occur as products of organic life; but all of these bodies require for their production the aid of an organic body.

With all their efforts, chemists have not succeeded in forming an organised tissue artificially, or any one of the compounds of which such tissues are made.

Q. Give some examples of inorganic and organic bodies.

A. *Glass*, *sulphur*, *antimony*, *iron*, &c., are inorganic bodies; while *sugar*, *alcohol*, *fat*, *glue*, &c., are organic bodies.

Q. What is DECAY, which we see in almost every form of matter?

A. Simply *chemical change.*

Q. Can we ANNIHILATE any material substance?

A. We *cannot;* what appears to us as annihilation is only a *chemical change.* When we cause a log of wood to disappear by burning, there is no annihilation; all the matter formerly contained in the wood exists as much after the combustion as before, only its state and condition have been changed.

Q. If we heat a piece of iron to redness, it becomes covered with a SCALE or RUST; and if it is now weighed, it will be found to have increased in weight. It has absorbed oxygen from the air. By what name do we designate the force or attraction which caused the oxygen of the air to unite with the iron?

A. The force of *affinity* or *kindred.*

Q. How will you define CHEMICAL ATTRACTION, or AFFINITY?

A. It is the *peculiar disposition* which *one body has to unite with a different body*, to the rejection of others which are dissimilar in their properties.

Q. Why will not OIL and WATER unite?

A. Because there is *no affinity* between the *oil* and the *water.*

Q. Why will ALCOHOL and WATER readily unite?

A. Because there is a *strong attraction* between the *elements* of the *alcohol* and those of the *water.*

Q. If we add a little POTASH to the OIL and WATER, what is the effect?

A. The *repulsion* of the oil and water is overcome, and the *three unite together* to form *soap.*

Q. If to the soap we add an ACID, what ensues?

A. The potash has so much *stronger affinity* for the acid than it has for the oil and water, that it quits both, and unites with the acid, leaving the oil and water to *repel* each other as before.

Q. Are the different DEGREES of AFFINITY, or ATTRACTION, which one body has for other substances CONSTANT in their action; or, in other words, may their attraction be always depended on?

A. These *elections are so constant*, that chemists have been enabled to *draw up tables* for the purpose of showing the order in which they occur.

Q. Where one element unites with another, what is the RESULTING PRODUCT?

A. An *acid*, a *base*, or a *neutral body*.

Q. What are ACIDS?

A. Acids are substances which *excite the taste of sourness* when applied to the tongue; they change the *blue juices* of vegetables to red, and combine with alkalies to form neutral compounds.

Q. What is an ALKALI?

A. An *alkali* is a body that possesses properties the *converse of those of an acid*. It has a *highly bitter, acrid taste*, changes the *blue juices* of vegetables *green*, or the juices of vegetables which have been changed red by an acid, back again to blue. Potash and soda are representatives of the alkalies.

Q. What is a NEUTRAL BODY?

A. One which possesses *neither acid nor alkaline* properties.

Q. What is a BASE in chemistry?

A. A body which may be *either* an *alkali* or a *neutral substance* which is capable of uniting with an acid. Thus, potash and soda, the oxide of iron, lime, &c., are bases.

Q. Where ACIDS and BASES UNITE, what is the resulting compound called?

A. A *salt*.

Thus, carbonate of lime (chalk), composed of carbonic acid and lime, is a salt; saltpetre, composed of nitric acid and potash, is another.

Q. Is the composition of all bodies FIXED and INVARIABLE?

A. It *is;* and a compound substance, so long as it retains its characteristic properties, must consist of the *same elements* united in the same proportions.

Q. When bodies combine chemically with each other, do they combine arbitrarily, or in some FIXED PROPORTIONS?

A. The proportions in which bodies combine chemically with each other are *fixed and invariable*.

Thus, water consists of one part of hydrogen united to eight parts (by weight) of oxygen. In whatever condition water may exist, whether in vapour, in springs, in the ocean, or as ice or snow, it is thus uniformly composed. When artificially prepared, by burning oxygen and hydrogen together, one grain, ounce, or pound of hydrogen is required for every eight grains, ounces, or pounds of oxygen. If one and a half ounces of hydrogen are taken, then a half ounce is left behind; if nine ounces of oxygen are taken, then one ounce will remain over uncombined.

Q. Into what TWO great CLASSES may the elements or simple substances be divided?

A. Into *metallic* and *non-metallic* bodies.

Q. To what ELEMENTS do we apply the term metallic?

A. To those which are *good conductors of heat and electricity*, which have a peculiar lustre, known as "metallic lustre," are

opaque, *insoluble in water*, and are *fusible* through the agency of heat. All the metals, with the exception of mercury or quicksilver, are solid bodies.

Q. What are METALLOIDS, or NON-METALLIC elements?

A. Those elements which do *not* possess the properties and characteristics of the *metals*.

They are wanting in metallic lustre, and are bad conductors of heat and electricity; the metallic elements being, on the contrary, good conductors. Most of the metalloids combine with hydrogen, while the metals do not; most of them also combine with oxygen to form acids, while the majority of the metals unite with oxygen to form bases. When compounds of the metallic and non-metallic elements are decomposed by the galvanic battery, the metals appear at, or are attracted by, the negative pole, while the metalloids appear at, or are attracted by, the positive pole. The non-metallic elements include solids, liquids, and gases.

Q. Name the NON-METALLIC ELEMENTS.

A. Oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, fluorine, chlorine, bromine, iodine, selenium, and boron.

Q. What are called the METALS?

A. They are—potassium, sodium, lithium, barium, strontium, calcium, magnesium, lanthanium, didymium, cerium, yttrium, erbium, terbium, norium, glucinum, aluminum, thorium, zirconium, silicium, titanium, tantalium, niobium, pelopium, tungsten, molybdenum, vanadium, chromium, uranium, manganese, arsenic, antimony, tellurium, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, mercury, silver, gold, platinum, palladium, rhodium, iridium, ruthenium, and osmium.

Q. Has one metal ever been CHANGED or transmuted into another?

A. No.

Q. What was it that the alchemists desired to EFFECT?

A. They endeavoured to transmute, or change, *lead* or some cheap metal *into gold*.

Q. Is there any reason for supposing that one metal can, or ever will be CHANGED into, or manufactured from, ANOTHER METAL?

A. At present we have *no good or sufficient reason* for supposing that this will ever be the case.

There is, however, some reason for supposing that some of the bodies which we now call simple or elementary are in reality compound; but we have not been able as yet to verify or prove this supposition.

Q. What were the FOUR ELEMENTS of the ancients?

A. They supposed all things to be composed of *fire*, *earth*, *air*, and *water*.

Q. Are any of these ELEMENTS?

A. *No:* air, earth, and water are, however, significant of the forms in which all matter exists; everything with which we are conversant upon the surface of the earth being either solid, liquid, or aëriform. Fire is only a visible and perceptible indication of changes occurring within the so-called elements.

Q. What do we mean by CHEMICAL ANALYSIS ?

A. The *separation* of the *elements* of a compound from one another, as when, by the aid of galvanism we decompose water into oxygen and hydrogen.

Q. What is SYNTHESIS ?

A. The *combining of the elements* of a compound together, so as to form that compound; as when oxygen and hydrogen are united by the agency of electricity, and form water.

CHAPTER XLIV.

OXYGEN.

Q. What is OXYGEN ?

A. A *gas*, colourless, tasteless, and odourless; it is heavier than atmospheric air, and is a non-conductor of electricity.

Q. Is oxygen a substance existing in GREAT ABUNDANCE ?

A. Oxygen is the *most abundant* of all known substances; it constitutes at least one-third of the solid mass of the globe, eight-ninths of all water, and nearly one-fourth part of the atmosphere; it also exists in most organic substances.

Q. What is the DIFFERENCE between OXYGEN and an OXIDE ?

A. Oxygen is a *gas*, and an *oxide* is a compound formed by the union of oxygen with other bodies.

Q. WHO gave this gas the NAME of OXYGEN ? and what is the signification of the word ?

A. Lavoisier gave it the name, which is derived from two Greek words οξυς (oxus), *an acid*, and γενναω (gennao), I produce.

This name was given to it because it was then thought to be the sole acidifying principle. Modern discoveries have rectified this error by proving the existence of acids in the composition of which there is no oxygen.

Q. Is OXYGEN ever found in a LIQUID or SOLID state ?

A. No: when pure, it is only known in the gaseous state; all efforts to reduce it to a liquid or solid condition by cold or pressure have completely failed.

Q. Of what USE is OXYGEN in the ATMOSPHERE ?

A. It sustains *animal life* and *supports combustion.*

Q. If an animal were immersed in oxygen gas, would it LIVE LONGER than in an equal volume of confined air ?

A. It *would;* at the same time, animal life could not be sustained for any great length of time in an atmosphere of pure oxygen.

Q. What is meant when it is said that the OXYGEN of the air "SUPPORTS COMBUSTION ?"

A. It means this: That the oxygen of the air is essential to combustion.

Q. How does the OXYGEN of the air make FUEL BURN?

A. The fuel is decomposed (by heat) into hydrogen and carbon; and these elements combining with the *oxygen* of the air, produce combustion.

Q. What is meant when it is said that OXYGEN "SUSTAINS LIFE?"

A. It means this: If a person could not inhale oxygen, he would *die.*

Q. What GOOD does this inspiration of OXYGEN do?

A. 1. It gives vitality or life to the blood; and
2. It is the *cause* of animal heat.

Q. What are OXIDES?

A. The *compounds* formed by the union of oxygen with other bodies bear the general name of oxides.

Generally, when we speak of oxides, we mean simple substances, which are united to a smaller quantity of oxygen than is necessary to form acids.

Q. What is the meaning of the terms PEROXIDE and PROTOXIDE?

A. When a substance unites with oxygen in two different proportions, that which contains the *greatest quantity* of oxygen is called *peroxide*, and that which contains a less quantity a *protoxide.*

Q. What is a SUBOXIDE?

A. Many metals have the power of uniting with oxygen in more than these two proportions. In this case the combination which contains a *less quantity* of oxygen than the *protoxide* is called a *suboxide*, and the *highest combination* of the substance with oxygen is called a *hyperoxide.*

Q. What is RUST?

A. The *oxidation* of iron in moist air.

"*Oxidation,*" combination with oxygen.

Q. Why does IRON RUST?

A. Because water is decomposed when it comes in contact with the surface of iron; and the oxygen of the water combining with iron, produces an *oxide*, which is generally called rust.

Q. Does iron RUST in DRY air?

A. No; iron undergoes *no change* in dry air at common temperatures.

Q. Why does hot iron SCALE and PEEL OFF when struck with a HAMMER?

A. Because the oxygen of the air very readily *unites* with the surface of *hot iron*, and forms a *metallic oxide* (or rust), which scales off when struck with a hammer.

Q. Why does PAINTING iron prevent it from RUSTING?

A. Because paint prevents the moist air from coming in *contact* with the *iron.*

Q. Why will BRIGHT IRON LOSE its POLISH by being put into a FIRE?

A. Because the oxygen of the air very readily unites with the

surface of *hot iron*, and forms a *metallic oxide*, which displays itself in this case by a *dull leaden* colour instead of a red *rust*.

Q. Why does ornamental STEEL (of a purple or LILAC colour) rust MORE READILY than polished WHITE steel?

A. Because the lilac tinge is produced by partial oxidation, and the process which forms rusts has, therefore, already commenced.

Q. If DRY AIR contains OXYGEN, why does it NOT RUST IRON as well as MOIST air?

A. Because *moisture* is always needed, in order to bring into action the *affinity of oxygen* for the iron at ordinary temperatures.

Q. Why does COPPER TARNISH?

A. The tarnish of copper is caused by its *oxidation;* that is, the oxygen of the air combines with the surface of the copper, and (instead of *rusting* it) covers it with a *dark tarnish.*

Q. Why does LEAD LOSE its BRIGHTNESS, and become DULL by being exposed to the air?

A. The *dullness* of the lead is caused by the presence of a *carbonate of the oxide.* When the oxide is formed through the agency of moist air, it attracts *carbonic acid* from the air, and (combining with it) produces a *carbonate*, which gives the *dull* tint to old lead.

Q. Why is it difficult to keep SILVER BRIGHT?

A. Because the *vapour* of the air *oxidises* its surface, and *tarnishes* it.

Q. Is GOLD affected by the ATMOSPHERE?

A. It is *not;* gold will *never combine* with oxygen of itself (that is, without aid).

Q. What OTHER METAL besides gold is capable of resisting the oxidising effects of air and moisture?

A. Platinum. Both gold and platinum, however, can be made to unite with oxygen through chemical agencies.

Q. Why are gold and platinum often used for the construction of DELICATE INSTRUMENTS?

A. Because they never *oxidise*, but retain their bright surfaces under all circumstances free from rust or tarnish.

Q. Can oxygen be made to combine with ALL the other elements?

A. It can be made to enter into combination with *all* the elementary bodies except *fluorine.*

There are several methods of generating oxygen gas. One of these methods is that which is detailed below, and for which it will be necessary to have the following apparatus: A large test-tube, about three-quarters of an inch in diameter, a bent glass tube, a pneumatic trough or basin, and a receiver.

The substance we shall require as the oxygen-yielding material is a mixture of two parts of chlorate of potash and one part of manganese, or rather the black oxide of manganese. These two substances must be rubbed together in a mortar. Pour about a tea-spoonful of the mixture into the test-tube, arrange the apparatus, and apply heat. Oxygen gas will come over rapidly. The first portions are contaminated with the common air in the apparatus. After this has been thrown away, we collect pure oxygen gas.

CHAPTER XLV.

HYDROGEN AND WATER.

SECTION I.—HYDROGEN.

Q. What is HYDROGEN?

A. It is an *inflammable gas*, one of the elements of which water is composed. The gas used in our streets is in great part hydrogen. Hydrogen, when pure, has neither taste nor odour.

Hydrogen derives its name from two Greek words *υδωρ* (udor), water, and *γενναω* (gennao), I produce.

Q. When was hydrogen gas DISCOVERED?

A. About the *middle of the eighteenth century*, and was termed inflammable air.

Q. Does HYDROGEN SUPPORT LIFE?

A. No; it destroys it, rather by *excluding oxygen* than by its own injurious effects.

Q. Does hydrogen gas, like oxygen, SUPPORT COMBUSTION?

A. No; it is highly combustible, but does not *support* combustion; with oxygen, it forms water.

Q. What are the PECULIAR CHARACTERISTICS of hydrogen gas?

A. 1. It is the lightest of all known substances;

2. It will burn immediately on being ignited; and

3. A lighted candle (immersed in this gas) will be instantly extinguished.

The following experiment shows the extreme lightness of hydrogen. Attach to one end of a thin slip of deal a glass or tumbler, and at the other end of the same slip of deal anything for the suspension of a counterpoise. Next support the slip by a fulcrum. Then, arranged under the suspended tumbler, let there be placed the bottle and pipe delivering hydrogen gas. The lightness of this gas is immediately proved by the tumbler being raised.

Q. For what USES are hydrogen gas employed?

A. 1. Owing to its levity, it is used to inflate *balloons;*

2. Burned with *oxygen*, it constitutes the oxy-hydrogen blowpipe; and, combined with carbon, it forms the ordinary illuminating gas; and

3. It is a powerful chemical agent.

"*Chemical agent*," a substance employed to effect chemical changes.

Q. What is a BLOWPIPE?

A. The blowpipe (*see fig.* 136) is a *tube* usually bent near the end, and terminated with a finely perforated *jet or nozzle.* This is used to

Fig. 136.

propel a *current or blast of air* from the lungs, *through the flame of a lamp or candle*, upon a substance which it is desired to fuse. A small conical flame is produced in this manner, possessing an intense degree of heat.

Q. What is an OXY-HYDROGEN, or COMPOUND BLOWPIPE?

A. An instrument in which the current or blast is formed of the *two gases*, *oxygen* and *hydrogen*, instead of atmospheric air. These gases are made to unite at the orifice of the blowpipe at the moment when they are ignited. The heat produced by their combustion and union is sufficient to melt almost every substance upon which the blast is directed.

Q. Can you describe the DRUMMOND LIGHT?

A. It is the ignited flame of a mixture of oxygen and hydrogen, projected against lime; the lime becomes intensely luminous, and forms the well-known Drummond light.

SECTION II.—WATER.

Q. What is WATER?

A. Water is a *fluid* composed of *oxygen* and *hydrogen*, in the proportion of eight parts of oxygen to one part of hydrogen.

Q. Why is WATER FLUID?

A. Water is fluid because its parts are *kept separate* by *latent heat.*

Q. Why is PUMP WATER HARD, or why is it called HARD WATER?

A. Because it contains matter which does *not so quickly dissolve* substances put into it.

Q. What is this HARDENING MATTER?

A. *Earth* and *minerals*, which mix with the water as it filters through the earth.

Q. What is MEANT by a MINERAL SPRING?

A. Spring water which contains mineral matter.

Q. When is a mineral water called CHALYBEATE?

A. When it contains *iron*, in some form, dissolved in it.

Q. Mineral springs exist in all parts of our country: what is the NATURE of the substances contained in them?

A. The great majority are only *impregnated with iron*, *salt*, or *sulphur*. Some few, however, contain many different substances.

Q. Why are springs containing iron in large quantities BENEFICIAL to some INVALIDS?

A. Because the iron contained in the water acts as a *tonic;* that is, it strengthens and invigorates the system.

Q. What QUANTITY of mineral matter is generally contained in comparatively pure natural waters?

A. Any water which contains *less than fifteen grains* of solid mineral matter in a gallon, is considered as *comparatively pure.* Some natural waters are known so pure that they contain only $\frac{1}{20}$th of a grain of mineral matter to the gallon, but such instances are very rare.

Waters obtained from different sources may be classed as regards comparative purity as follows :—

Rain water must be considered as the purest natural water, especially that which falls in districts remote from towns or habitations ; then comes river water ; next, the water of lakes and ponds ; next, spring waters ; and then the waters of mineral springs. Succeeding these, are the waters of great arms of the ocean, into which immense rivers discharge their volumes, as the water of the Black Sea, which is only brackish ; then the waters of the ocean itself ; then those of the Mediterranean, and other inland seas ; and last of all, the waters of those lakes which have no outlet, as the Dead Sea, Caspian, Great Salt Lake of Utah, &c. &c.

Q. How much SOLID MATTER is ordinarily contained in a gallon of sea water ?

A. From *twenty-two hundred to twenty-eight hundred grains.*

Q. How much SOLID MATTER is contained in a gallon of water from the Dead Sea ?

A. From *eleven thousand to twenty-one thousand grains*, or nearly one-fourth part of its weight.

Q. Does AIR exist in all natural waters ?

A. It *does : fishes* and *other marine animals* are dependent on the air which water contains for their existence.

Q. Would absolutely PURE WATER act as POISON to a fish ?

A. The fish would *die* of suffocation in such water.

Q. Where is the PUREST WATER to be found as a natural product ?

A. The purest natural water that can be procured is obtained by melting *freshly fallen snow*, or by receiving rain in clean vessels at a distance from houses.

Q. Why is FLOWING WATER not liable to become stagnant ?

A. Because its *currents carry away* all *contaminating substances* to the sea.

Q. What makes water BUBBLE and SPARKLE ?

A. The *air* or *gas* contained in it.

Q. Why is water fresh from the well or fountain more SPARKLING and REFRESHING than the same water after it has been for some time exposed to the air ?

A. All spring and well waters contain *atmospheric air*, *oxygen*, and *carbonic acid gases*, dissolved in them.

The amount of these substances contained in water depends upon its temperature, cold water dissolving and retaining a larger quantity than warm or tepid waters. When cold waters from springs or fountains are exposed to the air, they become elevated in temperature, and the gases contained in them escape, rendering the water flat and insipid. The principal agent in imparting a sparkle and freshness to water is atmospheric air, and not carbonic acid, as is often supposed and taught. The quantity of carbonic acid present in ordinary spring waters is generally inconsiderable.

Q. Why is it difficult to WASH with HARD water ?

A. Because the water contains *saline matters*, which deprive the water of a part of its solvent power.

Q. Why is it difficult to wash with SOAP in salt water ?

A. Because soap is *insoluble in salt water.*

Q. Why is RAIN WATER SOFT ?

A. Because it *does not contain earths or minerals.*

Q. Why is it MORE EASY to WASH with SOFT water than with HARD ?

A. Because soft water *unites freely* with soap, and dissolves it ; in

hard water the soap is either insoluble or becomes decomposed. The solvent power of water increases also with its purity or softness.

Q. When we wash with soap in water, what CHEMICAL ACTION takes place?

A. The soap is resolved into a *fatty substance* and an *alkali;* the alkali dissolves most of the organic substances which constitute the dirt which we wish to remove, and the greasy matter effects by its lubricity an easy washing away of the dissolved matter from other substances.

Q. Why do wood ashes render HARD water SOFT?

A. Because they contain a *powerful alkali*—potash, which removes or neutralises those impurities in the water which rendered it hard and unfit for washing.

Q. What is a PETRIFACTION?

A. An animal or vegetable substance *converted into stone.*

It frequently happens when an organic substance is saturated with water holding mineral matter dissolved or suspended in it, that as the particles of the substance gradually decay or become dissolved, their place is supplied by the mineral matter contained in the water; until at last all of the organic particles disappear, and a mass of mineral matter is substituted, which resembles the original substance in form and structure, and not unfrequently in colour. It is a mistake to suppose, as is often done, that the original particles are converted into stone; the process of petrifaction is one of replacement, not of conversion, a particle of mineral matter of the same form being substituted for each organic particle.

Q. Why does HOT water dissolve sugar and salt more readily than COLD water?

A. Because the heat of the water assists its *solvent action*, and opens for the water a passage through the particles of the substance.

Q. Why is the sea SALT?

A. The sea has undoubtedly derived all its salt by *washings from the land.* The streams that have flowed into it for ages have been constantly adding to its quantity, until it has acquired its present condition.

Q. Why is NOT RAIN WATER SALT, although most of it is evaporated from the SEA?

A. Because *salt* will *not evaporate*, and therefore, when sea water is turned into vapour, its *salt* is left behind.

Q. Is there MORE OR LESS of SALT in every spring, river, or lake?

A. The saline (salt) condition of sea water is but an increase on that of all lakes, rivers, and springs; they all contain *more or less* of *salt*, but their contents are continually changing and discharging themselves into the sea; therefore the salt does not accumulate.

Q. Is every lake into which rivers flow, and from which there is no outlet except by evaporation, a SALT LAKE?

A. It *is;* and it is curious to observe that this condition disappears when an artificial outlet is provided for such waters.

Such lakes are the Dead Sea, the Caspian, the Sea of Aral, and the Great Salt Lake of Utah, the saltness of all of which exceeds that of the ocean.

Q. What GOOD PURPOSES does the presence of so much salt in the ocean subserve?

A. It *depresses the freezing point* of the water many degrees,

thereby diminishing the dangerous facility with which fields of ice are formed in the polar regions; it also aids in preventing the *corruption of the water* by the accumulation of animal and vegetable remains.

Q. What are the SUBSTANCES extracted from the earth which we find in sea water?

A. The most abundant substance is *common salt;* next, certain *combinations of magnesia;* then *salts of lime*, with small proportions of *potash*, *iron*, *iodine*, and *bromine.*

Q. Are these substances found in MOST SPRINGS?

A. With the exception of iodine and bromine, they may be found in small quantities in almost *all springs* and *rivers.*

Q. Are those substances which we call IMPURITIES in water of any SERVICE to animal or vegetable systems?

A. They give to water its *freshness* and *sparkling properties;* pure distilled water is very disagreeable to drink. These substances are also generally beneficial to the systems of plants and animals, and are absorbed by them with the water.

Q. Does water form PART of the COMPOSITION of most bodies?

A. It enters directly into the composition of nearly all *bodies which can be crystallised* and most *organic compounds.*

Q. In what STATE does water exist in CRYSTALS?

A. It is *condensed* into a *solid form.* Thus a crystal of alum contains one-fourth part of its weight of water, yet it is perfectly dry and solid. If we expose it to heat, the water soon boils and evaporates from it.

Q. If the waters of the ocean were not moved by winds, currents, and tides, what would be the EFFECT?

A. The water would become *stagnant.*

Q. Will water contaminated with animal and vegetable matter, under some circumstances, PURIFY ITSELF?

A. Water contaminated with animal and vegetable matter, if kept for some time, undergoes a *spontaneous purification*, losing its offensive odour and colour, and depositing more or less sediment. Water for the supply of ships is well known to undergo this process of purification by fermentation; and the larger the quantity of destructible matter suspended in it, the more complete and rapid is its purification.

Q. What is a TIDE?

A. A *wave of the whole ocean*, which is raised to a certain height, and then sinks, after the manner of a common wave.

Q. What is the CAUSE of tides?

A. The *attraction of the sun and moon* upon the waters of the ocean. The moon being nearest to the earth, her attraction is six times greater than that of the sun. This attraction of the moon raises the waters of the ocean as they come under her influence by the motion of the earth on its axis.

Q. How MANY TIDES are there in a day?

A. Two in every lunar day—a period of 24 hours 49 minutes.

Q. What tides are the HIGHEST?

A. The *spring tides.*

Q. Why are they higher than at other periods?

A. Because the *sun and moon* are then in such a position that they exert their influence *together.* For every five feet of height in tide produced by the moon, the influence of the sun adds one foot.

Q. What are NEAP TIDES?

A. *Low tides.*

Q. Why are neap tides LOWER than other tides?

A. Because then the sun and moon have such positions that their attractive influence is *opposed to each other;* and for every six feet of the moon's tide, the opposite attraction of the sun takes away one foot.

Q. How FAST does the tide wave move?

A. The rate of movement of the tide wave depends upon the nature and depth of the sea bottom. With a depth of one fathom, its rate is *eight miles per hour;* and with one hundred fathoms, *eighty miles* per hour.

Q. Does the height of the same tide VARY in different places?

A. The height of the tide in different places depends much on the *configuration of the land;* the same tide may rise in one place three inches, and in another place thirty feet.

Q. At what PERIOD during the day is it HIGH water?

A. When the moon *passes the meridian*—that is, when it is nearly vertical over the place—the sea is elevated to the greatest extent, and it is said to be high water.

Q. WHEN is it LOW water?

A. When the moon is upon the *horizon*, or about six hours after high tide. As the moon passes the meridian below the horizon, another elevation occurs, so that we have the ebb and flow of the tide twice every day.

Q. How MUCH LATER does the tidal ebb and flow occur each day?

A. The tide becomes later every day by about *fifty and a half minutes*, which is the excess of a lunar day above a solar one: twenty-eight and a half minutes of the former being equal to twenty-seven and a half minutes of the latter.

Q. What is the CAUSE of ordinary SEA WAVES?

A. The *wind*, pressing unequally on the surface of the sea, depresses one part more than another; every depression causes a corresponding elevation, and these undulations are called *waves.*

It must be remembered that waves have no other than a *vertical motion*, i.e., up and down. Any substance, as a buoy, floating on a wave, is merely elevated and depressed alternately; it does not otherwise change its place.

Q. What is the SURF?

A. When the shore runs out very shallow for a great extent, the *breakers* are distinguished by the name of *surf.*

Q. What do we know concerning the MAGNITUDE and VELOCITY of ocean waves?

A. On the Atlantic, during a storm, the waves rise to a height of about *forty-three feet* above the hollow occupied by the ship; the total distance between the crests of two large waves being 559 feet, which distance is passed by the wave in about seventeen seconds of time.

Q. With WHAT VELOCITY is it estimated that such storm waves as above described travel?

A. At the rate of about *thirty-two miles per hour.*

A wave is a *form*, and not a thing; the *form* advances, but not the *substance* of the waves.

CHAPTER XLVI.

NITROGEN AND ITS COMPOUNDS.

SECTION I.—NITROGEN.

Q. What is NITROGEN?

A. An *invisible gas* existing largely in atmospheric air, and in most animal and vegetable substances.

Q. What are its principal CHARACTERISTICS?

A. 1. It is *not combustible;*

2. It does *not support animal life;* and

3. It is the *principal ingredient* in the composition of *atmospheric air.*

Q. Is nitrogen capable of SUSTAINING COMBUSTION?

A. No; nitrogen, like hydrogen, is *incapable* of sustaining combustion or animal existence, although it has no positive poisonous properties.

Q. Is there any DOUBT respecting the ELEMENTARY character of nitrogen?

A. There are some circumstances which have led to the belief that nitrogen is a *compound body*, and that its base is *metallic.* Nothing, however, is known with certainty concerning its real nature.

SECTION II.—COMPOSITION AND CHEMICAL PROPERTIES OF THE ATMOSPHERE.

Q. What is atmospheric AIR?

A. Oxygen and nitrogen mixed together, in the proportion of seventy-nine parts of nitrogen and twenty-one of oxygen.

Q. Is not the AIR we breathe almost wholly COMPOSED of NITROGE

A. It *is;* about *four-fifths of the air is nitrogen*, and the other one-fifth is *oxygen*.

Q. WHY is there so MUCH nitrogen in the air ?

A. The uses of nitrogen are in a great measure unknown. It has been supposed to act as a *diluent to the oxygen*, but it most probably serves some useful purpose in the economy of animals and vegetables, the exact nature of which has not been discovered.

Q. What would be the EFFECT if the proportion of oxygen in the atmosphere were INCREASED ?

A. The *inflammability* (the quality of catching fire) of most substances would be *increased*, fires would burn out very quickly, and the functions of life would be called into such rapid action as to soon exhaust the powers of the system.

Q. Are the two gases, oxygen and nitrogen, existing in the atmosphere, CHEMICALLY COMBINED, or merely mixed ?

A. They are *merely mixed*, and not combined with each other.

Q. Does the atmosphere always contain any OTHER INGREDIENTS besides oxygen and nitrogen ?

A. There is always in the air, at all places, *carbonic acid gas*, in variable proportions, besides watery vapour.

Q. Is the air collected on the tops of high mountains, over marshes, in hospitals, and over deserts, the SAME in CHARACTER and COMPOSITION ?

A. It is *not found to vary*, but is the *same* in all regions of the earth and at all altitudes.

Q. Are the component parts of air, oxygen, nitrogen, carbonic acid, and watery vapour, of different SPECIFIC GRAVITIES ?

A. They are all *different*, carbonic acid gas being the heaviest.

Q. Then, as we have before stated that they are merely mixed, and not combined, why do they not ARRANGE themselves in the order of their DENSITIES, or WEIGHTS, and FLOAT one upon the other, as oil and water do when mingled ?

A. Because of a wonderful principle or law of nature, that when two gases of different weights are mixed together, they *cannot remain separate, as fluids of different densities do*, but diffuse themselves uniformly throughout the whole space which both occupy.

Q. Carbonic acid is twenty times heavier than hydrogen gas ; if we fill the lower part of a tall jar with carbonic acid, and the upper part with hydrogen, will the two gases MIX ?

A. After a few hours the two gases will be found *equally mingled*, as much carbonic acid being at the top of the jar as at the bottom.

Q. Does this law appear to be OPPOSED to the principles of the law of GRAVITATION ?

A. It appears to be *opposed to it;* the only exception we are acquainted with in the natural world.

Q. How MUCH carbonic acid is estimated to exist in the atmosphere ?

A. About *one part* in *two thousand, by volume.*

Q. If this were all collected in one layer over the surface of the earth, how GREAT a THICKNESS would this layer or stratum have ?

A. About *thirteen feet.*

Q. Can we BREATHE carbonic acid?

A. *No;* any animal placed in it *dies instantly.*

Q. If, then, this singular law of the diffusion of gases did not prevail, would the surface of the earth be HABITABLE?

A. It would *not;* carbonic acid would fill up all the valleys and lower levels, separating every hill and elevation by an invisible ocean of poisonous gas, as impassable as the barrier between the dead and the living.

Q. Is it owing to this law that we are enabled to enjoy and perceive at a distance the ODOUR of a FLOWER GARDEN, or the PERFUME which has been opened in an apartment?

A. It is by this law that a vapour, arising by its own elasticity from a volatile substance, is *caused to extend its influence* and *mingle* with the surrounding atmosphere, until its effects become so enfeebled by dilution as to be imperceptible to the senses.

Q. If the oxygen and nitrogen of which our atmosphere is composed were combined together, instead of being merely mingled, what would the COMPOUND be?

A. A most *deadly poison.*

SECTION III.—COMPOUNDS OF NITROGEN.

Q. Does nitrogen readily ENTER into COMBINATIONS with other bodies?

A. Nitrogen enters into combination with but *few bodies*, and, when combined, has always a tendency to free itself.

Q. What CURIOUS FACT illustrates the non-conducting power of nitrogen?

A. Through an average size iron blast-furnace it is estimated that *six tons of air* pass every hour; during this transit the oxygen part of the air is most active in forming combinations, yet the nitrogen, although subject to precisely similar conditions of heat and contact, *emerges as it entered, uncombined.*

Q. What is the principal CHEMICAL COMPOUND which nitrogen forms with oxygen?

A. *Nitric acid*, or *aquafortis*, composed of five parts of oxygen united to one of nitrogen.

Q. What are the PROPERTIES of nitric acid?

A. It is a *liquid;* when pure, *colourless*, and highly *corrosive;* it attacks almost all dead, unorganised substances, and destroys living tissues.

Q. What is NITRE, or SALTPETRE?

A. *Nitric acid*, combined with *potash.*

Q. WHERE is saltpetre obtained?

A. It exists in the *earth* of many caves, and in the soil about barns and old buildings; in the *East Indies*, from whence the greater part of the saltpetre of commerce is obtained, it is found in great abundance in the earth of certain districts.

Q. How is the nitre supposed to ORIGINATE in the earth of these places?

A. From *decayed animal and vegetable substances*, which contain much nitrogen in their composition. In the chemical changes which take place when these substances decay, nitrogen is liberated, and

nitric acid formed, which last, uniting with potash previously existing in the soil, forms saltpetre.

Q. Can saltpetre be also MANUFACTURED?

A. It *can*, in the following manner:—Animal substances rich in nitrogen, such as hair, pieces of hides, flesh, &c., are mixed with earth containing lime or potash, and suffered to putrefy; during the putrefaction, by the chemical changes which take place, nitric acid is formed; this combines with the earth to form nitrates, which are afterwards extracted with water, and crystallised by boiling and evaporation.

Q. In what SIMPLE WAY can you often determine whether a body contains nitrogen?

A. By the *offensive smell* which a body containing nitrogen always produces when it is burnt; as, for example, the *odour* of *burnt hair*, *leather*, *flesh*, *bones*, &c.

Q. Do MANY of the offensive smells in nature result from the action of nitrogen?

A. Organic bodies which contain a large amount of nitrogen *always emit* a most *offensive smell* when they decay. The smell occasioned by the decaying of a dead human body, which contains much nitrogen, is one of the most offensive in nature.

Q. What is "LUNAR CAUSTIC?"

A. A compound of *nitric acid* and *oxide of silver*.

Q. Why, when lunar caustic is applied to the flesh, does it BURN and DESTROY it?

A. Through the agency of the *nitric acid* contained in it. Lunar caustic, when brought in contact with an organic substance, is readily decomposed, and the nitric acid set free to act upon the tissues.

Q. When nitrogen combines with hydrogen, what PRODUCT is formed?

A. *Ammonia.*

Q. In what CONDITION does pure ammonia exist?

A. As a *gas*, colourless, and of a strong, pungent smell, acting powerfully upon the eyes and nose.

Q. What are the PROPERTIES of ammonia?

A. It is a *strong alkali*, and combines with and neutralises the effects of acids.

Q. What is the SUBSTANCE used for the preparation of smelling salts, sal-volatile, &c.?

A. A compound of *ammonia* and *carbonic acid*—the carbonate of ammonia.

Q. Why is ammonia sometimes called "HARTSHORN" and "SPIRITS OF HARTSHORN?"

A. Because it was formerly obtained by distilling the *horns* of *deer* and *harts*, instead of bones.

Q. How is the AMMONIA of COMMERCE PRODUCED?

A. By distilling *animal substances*, especially bones. These substances contain nitrogen and hydrogen, which, at the moment of being set free by heat, unite with each other, and form ammonia.

Q. What is SAL-AMMONIAC ?

A. A compound of *chlorine* and *ammonium* — the chloride of ammonium.

Q. From WHENCE did the compound of ammonia derive its NAME ?

A. It was first manufactured in *Africa*, in the district of *Ammonia*, by the distillation of camels' dung; hence its name, "salts of ammonia."

Q. Is nitrogen an element in most EXPLOSIVE COMPOUNDS ?

A. Nitrogen being remarkable for its *unstable combinations*, is therefore an important element in most explosive compounds. It exists in gunpowder in the saltpetre, which constitutes nearly three-fourths the weight of good powder.

Q. Will SALTPETRE of ITSELF EXPLODE when burnt ?

A. It will *not*.

Q. What, then, has been the OCCASION of the fearful EXPLOSIONS which have taken place when warehouses filled with saltpetre have been consumed by fire ?

A. Saltpetre, when burning, *liberates a large amount of oxygen; water*, when thrown upon a hot fire, is frequently *decomposed*, and hydrogen is set free; hydrogen and oxygen form a terribly explosive compound. Again, the other products arising from the combustion of the different substances contained in the warehouses, united with the products arising from the decomposition of the saltpetre, would produce explosive compounds.

Q. Are there MANY OTHER compounds more explosive than gunpowder ?

A. There *are:* the most explosive compounds known are produced by the union of *nitrogen with iodine and chlorine*. The iodide of nitrogen explodes when it is slightly jarred, or when its temperature is elevated in the slightest degree, shattering all solid bodies near it. A single drop of the chloride of nitrogen will also produce most destructive effects.

Q. Nitrogen, as we have shown, by uniting with oxygen, forms an acid; with hydrogen, an alkali—ammonia: what is the PRODUCT formed when NITROGEN unites with CARBON ?

A. It is called *cyanogen*, which is the principal element in forming that most terrible and deadly poison, *prussic acid*.

Q. Why are KERNELS of PEACH STONES poisonous ?

A. Because they contain *prussic acid*.

Q. What peculiar ODOUR has prussic acid ?

A. The odour of *peach blossoms*.

Q. What is the well-known LAUGHING GAS composed of ?

A. One part of *oxygen* united to two of *nitrogen*.

CHAPTER XLVII.

CARBON AND ITS COMPOUNDS.

Q. What is CARBON ?

A. A *solid elementary or simple substance*, generally of a dark or black colour, well known under the forms of *charcoal*, *lamp-black*, *coke*, &c.

Q. Carbon occurs in nature CRYSTALLISED in two forms : what ARE THEY ?

A. The *diamond* and *graphite*.

Graphite, known by the names of plumbago and blacklead, is used for making pencils for drawing and writing.

Q. What PECULIAR PROPERTIES does the DIAMOND possess ?

A. It possesses a degree of *hardness* superior to that of any other mineral ; it *scratches* all other bodies, but it is scratched by none ; it acquires *positive electricity* by friction, but does not retain it ; and it possesses either *single* or *double refraction*, according to its crystalline form.

Q. Can you give an EXAMPLE of carbon in its UNCRYSTALLISED state ?

A. *Lamp-black*, the soot produced by the imperfect combustion of oil or resin, is pure carbon in its *uncrystallised* or *amorphous* state.

Amorphous, "shapeless," "without form."

Q. What is CHARCOAL ?

A. Charred wood.

Q. Can all animal and vegetable substances, by partial burning, be changed into COAL ?

A. They *can*.

Q. What is TINDER ?

A. Charred linen.

Q. In the charring of animal and vegetable substances, do WE FORM CHARCOAL, or did it exist there before ?

A. The carbon or coal existed there *previously*, though in chemical combination with other bodies, which are principally driven off by heat, as is apparent from the fact that a charred body weighs much less than the original substance ; animal and vegetable substances consist, therefore, in part of coal.

Q. How many VARIETIES of coal are there in the mineral kingdom ?

A. *Brown coal*, sometimes called *lignite*, *bituminous coal*, and *anthracite coal*. Lignite is simply wood charred by the action of the earth in which it has for a long period been buried.

Q. What OCCASIONS the DIFFERENCE between bituminous and anthracite coal ?

A. Bituminous coal contains a large amount of *bitumen* and other *pitchy* substances which readily ignite and burn with smoke and

flame. In anthracite coal these substances have been driven out; it is therefore a purer variety of carbon, and burns without smoke or flame.

Q. What is COKE?

A. Coke is *bituminous coal* which has been heated apart from the air, until its volatile portions are in a great measure *driven off.*

Q. What is SOOT?

A. Coal in a state of *minute division*, which is deposited from the flame of bituminous or pit-coal, wood, oil, resin, &c., when, during the combustion of these substances, there is an insufficient supply of air.

Q. What is ANIMAL CHARCOAL, IVORY-BLACK, OR BONE-BLACK?

A. The charcoal obtained by heating animal substances, such as *ivory shavings*, *bones*, &c., in close vessels.

Q. How is CHARCOAL PREPARED?

A. By *charring wood* in mounds or pits, covered with turf or soil in such a way as to exclude in a great degree the admission of air, and thus prevent complete combustion. The finest kinds of charcoal, such as are used in the manufacture of gunpowder, are prepared by heating wood in close iron cylinders.

Q. How MUCH charcoal can be obtained from a given weight of dry wood?

A. From *one-third* to *one-fourth* of the original weight of the wood.

Q. What singular CHEMICAL PROPERTIES does charcoal possess?

A. The property of *absorbing* the *odoriferous* and *colouring principles* of most animal and vegetable substances.

Q. By WHAT METHOD is loaf-sugar freed from its original brown colour, and rendered so pure and sparkling white?

A. By filtering in solution through *animal charcoal* or bone-black.

Q. Does charcoal, after it has been used for removing impurities and absorbing colours, lose its CHEMICAL PROPERTIES?

A. In a *great degree;* they can, however, be restored by heating the charcoal.

Q. Why is a CHARCOAL fire HOTTER than a WOOD fire?

A. Because charcoal is very pure carbon; and as it is the *carbon* of fuel which produces the glowing heat of combustion, therefore the *purer* the carbon, the more intense will the heat of the fire be.

Q. Why will not STONES do for fuel as well as COAL?

A. Because they contain no hydrogen, *and little* or *no* carbon.

Q. How are the BEST BLACK-LEAD PENCILS made?

A. The plumbago is *ground to powder*, and subjected to extreme pressure simultaneously with the abstraction of all remaining traces of air by the air-pump. The result of this treatment is a block, which, when sawed, furnishes the little bars which, enclosed in a cedar case, constitute a pencil.

Q. If you heat charcoal in a vessel, with an entire exclusion of the air, what CHANGE takes place?

A. It seems to *melt* when subjected to intense heat, the air being excluded, and assumes a somewhat metallic appearance.

Q. How do we KNOW that the diamond is simply CARBON CRYSTALLISED?

A. Because it is *combustible*, and can be *entirely consumed* by fire; the products of the combustion being the same as those derived from combustion of pure charcoal.

Q. Have we any KNOWLEDGE of the MANNER in which the diamond is formed?

A. We have *but little* definite knowledge upon the subject. There is good reason for supposing, however, that the diamond was once in a *fluid* or *semi-fluid* state. Sir David Brewster inclines to the opinion that the diamond is simply a drop of fossilised gum.

Q. From what COUNTRIES is the supply of diamonds chiefly derived?

A. Since the year 1720, when diamonds were first discovered in *Brazil*, that country has been their chief source; before which period they were exclusively brought from the *East Indies*

Q. Who first succeeded in BURNING the diamond?

A. *Lavoisier* first proved it to contain carbon, by throwing the sun's rays, concentrated by a powerful lens, upon a diamond contained in a vessel of oxygen gas. The diamond was consumed entirely, oxygen disappeared, and carbonic acid gas was generated.

Q. The diamond being the hardest substance in nature, and capable of scratching all other bodies, in WHAT WAY are lapidaries enabled to cut and shape it?

A. It can only be cut or polished by portions of its *own substance;* hence *diamond powder* is universally employed for that purpose; such stones as, on account of their inferior colour or their flaws, are valueless as gems, being broken down into powder for the purpose of cutting others.

Q. Into WHAT CLASSES are cut diamonds divided?

A. Into *brilliants* and *rose diamonds.* The former, which are the most beautiful and valuable, may be recognised by their flat summits, whereas the summits of rose-diamonds are peaked.

Q. How is the WEIGHT of the diamond ESTIMATED?

A. In *carats;* 150 of which are equal to one troy ounce, or 480 grains.

Q. What is the LARGEST DIAMOND in existence?

A. The largest known diamond is one of the *ugliest* and most uninviting in its appearance. It belongs to the *crown of Portugal.*

This diamond, from its astounding value, which is set down at £5,644,000, has never been entrusted to any diamond-merchant to cut or polish. In size it resembles a large turkey-egg, with a piece notched out of the side; it is semi-transparent on the surface, and weighs one thousand six hundred and eighty carats.

Q. What is the most VALUABLE cut diamond?

A. A diamond in the *royal sceptre of Russia.*

Its weight is seven hundred and seventy-nine carats, and its value, being without a

flaw, and of very fine water, £4,854,000. Russia has another diamond worth £297,000, and France a sky-blue diamond, valued at £150,000. The Koh-i-noor diamond, which excited so much attention at the Industrial Exhibition of 1851, weighed two hundred and eighty carats, and its worth was estimated at £2,000,000 sterling.

Q. In what SITUATIONS is the diamond found?

A. The diamond is not found in rocks, but in *sand* and *gravel* in the *beds of streams*, or on the slopes of hills and mountains.

Q. How great a heat is required to effect the COMBUSTION of the diamond?

A. About *five thousand degrees* Fahrenheit.

Fahrenheit's scale of the thermometer is here referred to, his being generally used in England. When, in connection with degrees of temperature, we employ the letter F., it means by Fahrenheit's scale and measurements.

Q. What is STEEL?

A. *Iron* chemically combined with *carbon.*

Q. How is STEEL made from IRON?

A. The iron is surrounded *with charcoal*, and placed, during six or eight days, in a furnace intensely heated; the carbon unites with the iron, and forms what is called "carburet of iron" (or steel).

Q. How MUCH CARBON is there contained in steel?

A. About *two and a half pounds* of carbon are contained in every hundredweight of steel.

Q. What constitutes the DIFFERENCE between cast iron and wrought or malleable iron?

A. Cast iron contains a large quantity of *carbon*, four or five pounds to the hundred, while malleable iron contains *very little* carbon.

Q. What is essentially the PROCESS for converting cast iron into wrought iron?

A. *Depriving* the cast iron of its *carbon.*

Q. In what STATE is carbon supposed to exist in STEEL?

A. There is some reason for supposing that carbon exists in steel in the *form of the diamond.*

Q. What CURIOUS THEORY has been proposed to explain the reason of the peculiar cutting properties of steel edges, or the so-called "hair edge" of a razor?

A. That the remarkable fine cutting properties of steel edges is due to a *minute form of the diamond* imbedded in the edge of the metal; and it has been supposed that by the dipping a razor in warm water the metal expanded and forced the sharp edges of the imbedded carbon into such positions as to cut with greater ease.

Q. Has the diamond been formed as yet ARTIFICIALLY?

A. M. Despretz of Paris, in the year 1853, undoubtedly succeeded with a galvanic battery in *fusing* and *crystallising carbon*, thus producing a quantity of *microscopic diamonds.*

Q. What is CARBONIC ACID GAS?

A. It is formed by carbon and oxygen. Its chemical composition is one atom of carbon united to two of oxygen.

Q. What GAS is generated by a lighted CANDLE or LAMP?

A. Carbonic acid gas,—formed by the union of the *carbon* of the *oil* or *tallow* with the *oxygen of the air*.

Q. When does CARBON most readily UNITE with OXYGEN?

A. 1. When its temperature is raised;

2. Carbon in the *blood* unites readily with oxygen during *respiration;* and

3. Carbonic acid is formed in large quantities during the chemical changes which we call *fermentation*.

Q. Is carbonic acid WHOLESOME?

A. *No;* it is fatal to animal life.

Q. When persons commit suicide by building a charcoal fire in a closed room, what OCCASIONS their death?

A. The *inhalation of carbonic acid*, which is generated by the combustion of the charcoal.

Q. How can we ASCERTAIN if a pit or well contains CARBONIC ACID GAS?

A. By letting down into it a lighted candle. Where a *candle will burn*, a *man can live;* but *what will extinguish a candle*, will also *destroy life*.

Q. Why does a CROWDED ROOM produce HEADACHE?

A. Because we breathe air vitiated by the *crowd*, deprived of its due proportion of oxygen, and *loaded* with carbonic acid.

Q. Is ALL the NITROGEN REJECTED by the lungs?

A. *Yes;* *all* the nitrogen of the air is always *expired*.

Q. How MUCH OXYGEN does a full-grown person consume per hour?

A. It is calculated that an adult of average size absorbs about *a cubic foot of oxygen per hour* by respiration, and consequently renders five cubic feet of air unfit for breathing, since every five cubic feet of air contains one cubic foot of oxygen. It is also calculated that two wax or sperm candles absorb as much oxygen as an adult.

Q. To keep the air of a room pure, HOW MUCH FRESH AIR should be allowed to pass in per hour?

A. *Five cubic feet for each person*, and *two and a half cubic feet for each candle*, should be allowed to pass in, and an equal quantity to pass out.

Q. Why is it dangerous for persons in a STATE of PERSPIRATION to expose themselves to a COLD CURRENT of air?

A. The heated surface of the body receives a *chill*, by which the integuments are caused to contract, and the pores of the skin become *closed;* the fluids, which ought to have been permitted to escape by cuticular transpiration, are driven back into the blood, producing, as an immediate or ultimate consequence, rheumatisms, colds, fevers, and, in more cases than are ever known or acknowledged, premature and ultimate death.

Q. Why do PERSONS who are much in the OPEN AIR enjoy the best HEALTH?

A. Because the air they inhale is much more pure than the air of close and confined rooms.

Q. Do TREES and FLOWERS purify the air?

A. Yes; by absorbing *carbonic acid*, and giving forth *oxygen*.

Q. Whether is TOWN or COUNTRY AIR the best?

A. Country air is more pure than that of towns, because there are fewer people in the country, and they are not so closely packed as they are in towns; because the air is not vitiated by the sewers and drains; because the air can circulate more freely; and because vegetation absorbs the carbonic acid.

Q. What BECOMES of the carbonic acid generated in crowded cities?

A. It is gradually diffused through the air, absorbed by vegetation and by water, and wafted by the winds to different localities.

Q. What is CHOKE DAMP?

A. *Carbonic acid gas* accumulated at the bottom of wells and pits, which renders them noxious, and often fatal to life. It is called *choke* damp, because it *chokes* (or suffocates) *every animal* that attempts to *breathe it.*

Q. Why is not this carbonic acid TAKEN UP by the AIR and DIFFUSED, as it is in cities?

A. Because (being heavier than common air) it cannot readily rise from the well or pit; and no wind can get to it to blow it away.

By the chemical law of diffusion, a portion of the carbonic acid which accumulates at the bottom of wells and pits, is removed; but in many cases the quantity removed is more than equalled by an increased supply.

Q. How MUCH CARBON in the form of carbonic acid passes through the lungs of a healthy person every twenty-four hours?

A. The quantity would be very accurately represented by a *mass of charcoal* of the weight of *three pounds.*

The volume of carbon in the atmosphere, although it forms but one per cent. of the carbonic acid existing in it, exceeds in amount all the carbon that is stored in the earth in the form of coal, or spread over its surface in the form of animals or vegetables.

Q. What are the CHIEF SOURCES of CARBONIC ACID?

A. *Combustion*, *respiration* of men and animals, the *decomposition of organic substances*, and the *exhalations of volcanoes.* Carbonic acid also exists in large quantities in the atmosphere, in most waters, and combined with minerals in a solid state, as in marble, which consists of lime united to carbonic acid.

Q. From WHAT SOURCE is the largest quantity derived?

A. From rotting vegetable or animal matter.

Q. How can we HINDER the ACCUMULATION of CARBONIC ACID?

A. By throwing quantities of quicklime where such decay is likely to take place.

Q. What EFFECT does this produce?

A. The quicklime absorbs the carbonic acid.

Q. What is the RESULT?

A. A combination called *carbonate of lime.*

Q. Does rain act in the SAME WAY as quicklime ?

A. It will prevent carbonic acid from accumulating, by dissolving it.

Q. Is volcanic action (the action of fiery mountains) a PROLIFIC source of carbonic acid ?

A. *Large volumes* of *carbonic acid gas* arise from volcanoes. At one place near Vesuvius, in Italy, it is said that six hundred pounds' weight are discharged every twenty-four hours.

Q. Why does YEAST cause bread to RISE ?

A. Yeast produces *fermentation* in the dough ; fermentation produces *carbonic acid*, which, striving to escape, puffs up the dough and causes it to rise or become light.

Q. Why does wood DECAY ?

A. Because the oxygen of the air unites with the carbon and hydrogen of the wood, and forms carbonic acid and *water*.

Q. Why is QUICKLIME formed by burning limestone in a KILN ?

A. Because the carbonic acid (which was combined with the lime) is *driven off* by the heat of the kiln ; and the lime becomes *quick* or *caustic*.

Q. What is MORTAR ?

A. Mortar is *quicklime*, mixed with sand and water.

Q. Why does MORTAR become HARD after a few days ?

A. Because the lime reimbibes from the air the carbonic acid which had been *expelled by fire*, and the water used in mixing the mortar also flies off, leaving a compound of carbonate and hydrate of lime.

Q. Wherein does LIMESTONE DIFFER in appearance from quicklime ?

A. *Limestone* is a *hard, rocky substance ;* but *quicklime* is friable.

Q. Is CARBONIC ACID a CONSTITUENT of most spring and well waters ?

A. Carbonic acid exists, either in a pure state or in combination with lime or magnesia, in *most waters*.

Q. From WHAT SOURCES do spring waters derive their supplies of carbonic acid ?

A. *Cold water* absorbs *carbonic acid* from the atmosphere, and expels it again when the temperature of the water becomes elevated. Water, in trickling through the soil where organic substances are decaying, freely absorbs carbonic acid.

Q. Why should HARD WATER (used for washing) be EXPOSED to the AIR ?

A. Because it is made *more soft* by exposure to the air.

Most spring water holds lime in solution as a bicarbonate, in consequence of the presence of abundant carbonic acid. Carbonic acid escapes by exposure to air, and the lime is, consequently, deposited as a carbonate.

Q. WHY is HARD WATER made more SOFT by exposure to the air ?

A. 1. Because the mineral salts (which cause its hardness) subside ; and

2. Because the carbonic acid of the water makes its *escape* into the air.

Q. Can carbonic acid be made SOLID ?

A. By means of *intense cold* and *great pressure* carbonic acid can be both liquefied and made solid. In the solid state it resembles SNOW.

Q. Can the power of water for dissolving carbonic acid be increased ?

A. Yes; carbonic acid may, by pressure, be forced into water. *Effervescing draughts* are made upon this principle.

Q. From what is the word EFFERVESCENCE DERIVED ?

A. From the Latin word *effervesco* (to boil).

Q. What is the CAUSE of EFFERVESCENCE ?

A. The carbonic acid of the drink is forced *into the liquor by pressure*, and *absorbed* by it; but when the cork (or pressure) is removed, some of the carbonic acid flies off in *bubbles* or *effervescence.*

Q. Why does SODA-WATER EFFERVESCE ?

A. In soda-water there is forced *eight times its own bulk of carbonic acid gas*, which makes its escape in *effervescence* as soon as the *pressure is removed.*

Q. Why does the EFFERVESCENCE of soda-water and ginger-beer SO SOON GO OFF ?

A. Because the *carbonic acid* (which produced the effervescence) very *rapidly escapes* into the air.

Q. Why does the cork of a champagne bottle FLY OFF the instant it has been LOOSENED from the neck of the bottle ?

A. Because the quantity of *carbonic acid gas* contained in the liquor can no longer be confined, and, seeking to escape, *drives out the cork* with great violence.

Q. Why is HARD WATER MORE AGREEABLE TO DRINK than soft water ?

A. Chiefly because it contains *carbonic acid.*

Q. What occasions the pale BLUE FLAME which may be observed to play about ignited charcoal, or at the lower edge of the flame of a gas-light or candle ?

A. The presence of a gas, called *carbonic oxide.*

Q. What is CARBONIC OXIDE ?

A. A compound of *carbon* and *oxygen*, containing one-half the quantity of oxygen that carbonic acid does.

Q. What are the PROPERTIES of carbonic oxide ?

A. It is a *deadly poison* when inhaled, and is combustible.

CHAPTER XLVIII.

COMBUSTION, RESPIRATION, AND NUTRITION.

SECTION I.—COMBUSTION.

Q. What is COMBUSTION?

A. Every species of combustion with which we are familiarly acquainted is the rapid *chemical union* of the *oxygen* of the air with a combustible or explosive body, attended with *light* and *heat*.

Q. How may combustion, as we ordinarily see it, be REGARDED?

A. It may be regarded as simply a *process of oxidation*.

Q. What is the difference between combustion and explosion?

A. Simply the difference in *rapidity of action* in the two cases. In combustion, the combustible and the supporter of combustion are brought together by degrees, as in the flame of a lamp or candle; but in an explosion, the combustible and supporter of combustion are mingled together, and the whole action occurs at once.

Q. What becomes of the OXIDISED PRODUCTS of combustion?

A. They for the most part *combine with oxygen* to form *gases* and *vapours*. We apply to these products the general term *smoke*.

Q. What is an ESSENTIAL REQUISITE to every process of combustion?

A. That there should be a *free supply of air*, and that the products of combustion, or the *smoke*, should be *conducted off*.

Q. Why, when we burn a candle or a piece of wood in the air, does there always seem to be a LOSS of MATTER?

A. Because the results of combustion in these cases are either *gases* or *vapours*, the existence of which, not being apparent to common observation, requires to be made known by experiment.

Q. How is HEAT EVOLVED by combustion?

A. By chemical action. As latent heat is liberated, when water is poured upon lime, by chemical action, so latent heat is liberated in *combustion* by chemical action also.

Q. What CHEMICAL ACTION takes place in combustion?

A. The elements of the fuel combine with the oxygen of the air.

Q. Is there not always an INCREASE in WEIGHT during the combustion of burning materials, rather than a loss?

A. The products of combustion always *exceed the weight* of the original substance burned, by an amount equal to the weight of the oxygen gas absorbed during the combustion.

Q. What is the TEMPERATURE required to induce the combination of oxygen with any substance called?

A. The *burning point*.

Q. Is this point DIFFERENT for DIFFERENT SUBSTANCES?

A. *It is;* thus phosphorus will combine slowly at 77 degrees F., but does not enter into rapid combustion until the temperature is raised to 104 degrees F. Charcoal burns slowly below a red heat.

Q. Is the QUANTITY of HEAT given out, when a body combines slowly with oxygen, the same as when it combines rapidly with it, the relative quantities of the combining bodies remaining the same in both cases?

A. The total quantity of heat given out is the *same*, whether the combustion takes place *slowly* or *quickly;* but in the case of slow combustion, the heat is much less intense, and often becomes insensible, because during the long time occupied in combination the greater part is carried away by conduction.

Q. Is the QUANTITY of LIGHT given out the same whether the combustion be rapid or slow?

A. No; the quantity of light given out during the combination of oxygen with a given quantity of a combustible body *varies greatly*, according to the rapidity of the combustion.

Q. What is FLAME?

A. Burning *gas* or *vapour.*

Q. What does the BRIGHTNESS, or ILLUMINATING POWER, of flame depend on?

A. It depends on the *degree of heat* in part, but mainly on the presence or absence of solid particles in the flame, which may act as radiating points.

Q. How can you ILLUSTRATE this?

A. Pure *alcohol*, containing few solid particles, emits but a *feeble light* when burning, even if its temperature is the highest possible; but if we mix *turpentine* with it, which contains a large quantity of carbon, we have the ordinary burning fluid, which burns *very brightly*, its brightness increasing with the temperature to which the particles of carbon are raised.

Q. Are there solid particles in EVERY illuminating flame?

A. There *are;* and if we present a cold surface to the flame, they become deposited on it in the form of soot.

Q. When we say a lamp SMOKES, what do we mean?

A. That the *solid parts* of the flame are passing off in an unconsumed state.

Q. When the flame burns properly, why does the smoke CEASE to be EMITTED?

A. Because the solid particles of carbon constituting the smoke are *burned up*, or are completely united with oxygen, forming an invisible gas—carbonic acid.

Q. From WHAT SOURCE is the carbon, constituting the illuminating particles in the one case, and the soot in the other, derived?

A. It was originally a part of the *burning* or *combustible body.*

Q. When will a flame SMOKE?

A. When the supply of oxygen received from the air is *insufficient to consume all the carbon* which the heat separates from the combustible body in the form of soot.

Q. What BENEFIT arises from surrounding a flame with a glass cylinder or chimney open at the bottom and top?

A. When a flame burns without a chimney, the hot air radiates in *all directions;* but when it is surrounded by a chimney, the hot air is confined within the walls of the cylinder; consequently, the hot air will issue rapidly from the top of the chimney, and cold air will enter equally fast at the bottom to replace it. In this way a constant current of fresh air is kept up through the centre of the flame, causing a more perfect combustion, and a brighter and stronger flame.

Q. Why are lamp chimneys made CONICAL, or caused to contract at a certain height above the burner, so as to form a shoulder?

A. By the contraction of the cylinder the draught of air is *broken*, and thrown in *upon the flame* at an angle.

Q. Is not the supply of air LESSENED by this contrivance?

A. It is; but the *new direction* given to the draught is a gain, since that part of the current which, in a straight cylinder, would pass along the inner surface without taking part in the combustion and at the same time cooling the flame, is almost wholly removed by contracting the cylinder.

Q. For what TWO PURPOSES do we effect combustion?

A. For the sake of *obtaining heat or light.*

Q. Can we with advantage so regulate combustion as to obtain economically both HEAT and LIGHT at the same time, and by ONE operation?

A. The nature of the chemical process, and of the bodies employed, as well as in most cases the practical arrangements, render it *impossible* to attain *both ends with advantage* in the same time.

Q. What is FUEL?

A. Any substance which serves as *aliment* or *food* for *fire.* In ordinary language, we mean by fuel the peculiar substance of plants, or the products resulting from their decomposition, designated under the various names of wood, peat, and coal.

Q. What is wood FORMED of?

A. *Carbon*, *hydrogen*, and *oxygen*, combined together, make up the chief part of its bulk; all wood also contains water.

Q. At what PERIOD of the YEAR does wood contain the greatest amount of water?

A. In the *spring* and *summer*, when the sap flows freely, and the influence of vegetation is the greatest.

Q. Why is wood generally cut in the WINTER SEASON?

A. Because at that season there is but *little sap* in the tissues, and the wood is drier than at any other period.

Q. Why is it difficult to INFLAME COAL or hard wood with the blaze of a match?

A. *Coal* and *hard wood*, on account of their density, are good conductors, and carry off the heat of the kindling substance, so as to extinguish it, before they themselves become raised to the temperature necessary for their combustion.

Q. Why is it easy to ignite LIGHT FUEL with a small blaze?

A. Light fuel, being a slow conductor of heat, *kindles easily*, and from the admixture of atmospheric air in its pores and crevices, burns out rapidly, producing a comparatively temporary, though often strong heat.

Q. In recently-felled wood what PROPORTION of its WEIGHT is WATER?

A. From *one-fifth* to *one-half*.

Q. After wood has been dried in the air for ten or twelve months, HOW MUCH WATER does it usually contain?

A. From *twenty* to *twenty-five per cent*.

Q. Why do we call some woods HARD, and others SOFT?

A. This distinction is grounded upon the *facility* with which they are *worked*, and upon their power of *producing heat*. Hard woods, as the oak, beach, walnut, elm, and alder, contain in the same bulk more solid fibre, and their vessels are narrower and more closely packed than those of the softer kinds, such as pine, larch, chestnut, &c.

Q. Will the wood of a given species of tree growing in one situation be DENSER than when growing in another situation?

A. *High situations*, much *exposed* to the *wind*, and a *poor soil*, cause the vessels of the wood to be less developed, and consequently more closely packed, than is the case with wood which is protected and growing on the more fruitful soil of valleys.

Q. Why is it UNPROFITABLE to burn green wood or wet coal?

A. It is a well-known law of heat that the *evaporation of liquids*, or their conversion into *steam*, consumes or renders latent a great amount of caloric. When green wood or wet coal are added to the fire, they abstract from it by degrees a sufficient amount of heat to convert their own sap or moisture into steam before they are capable of being burnt. As long as any considerable part of this fluid remains unevaporated, the combustion goes on slowly, the fire is dull, and the heat feeble.

Q. Is there any TRUTH in the remark often made, "that it is economy to burn GREEN WOOD because it is more durable, and therefore, in the end, more cheap?"

A. *No;* it is true that the consumption of green wood is *less rapid* than dry; but to produce a given amount of heat, a far greater amount of fuel must be consumed.

Q. What is PEAT?

A. Peat is *composed of carbon*, produced by the *decay of mosses*, *grasses*, and *water-plants* of various species, which in the course of time accumulate in the bottoms of bogs and swamps.

Q. In ordinary fuel, what THREE ELEMENTS enter into the process of combustion?

A. *Hydrogen gas*, *carbon*, and *oxygen* gas; the two former in the fuel, and the latter principally in the air which surrounds the fuel.

Q. Do BLAZING COALS burn MORE RAPIDLY than red-hot coals?

A. They do; the *inflammable gases* of the coal which are then *escaping* making the coal itself burn *much quicker* than would otherwise be the case.

Q. Does not a CLEAR RED FIRE burn a long time without going out?

A. Yes; it will burn *much longer* than a blazing fire, for the reason already stated.

Q. When a fire is RED HOT there is LESS SMOKE than at other times: how is this?

A. As all the coals are *burning*, or in a state of *combustion*, there is but little *carbon* to escape in smoke.

Q. The flames of a fire are not all of ONE COLOUR: how is this?

A. It arises from the *difference of material* which is burning.

Q. Are these DIFFERENCES observable in coal fires?

A. Pure hydrogen produces a *bluish flame;* light carburetted hydrogen, a *yellowish flame;* heavy carburetted hydrogen, a *white flame.*

Q. When a coal FIRE is LIGHTED, why are paper and wood laid at the BOTTOM against the GRATE?

A. That the flame may *ascend* through the fuel to heat it. If the fire were kindled from the *top*, the flame *would not come in contact* with the fuel placed below.

Q. Why will not WET MATERIALS KINDLE a fire?

A. Because the moisture prevents the oxygen of the air from getting to the fuel, and the heat of the fire is drawn off by the conversion of water into *steam.*

Q. Why do TWO PIECES of wood burn better than ONE?

A. 1. Because they serve in some measure to intercept the heat of the passing smoke and *throw it on the fuel;* and

2. The air, impinging against the pieces of wood, is *thrown upon the fire* in a kind of *eddy* or draught.

Q. Why are CINDERS LIGHTER than COALS?

A. Because they are full of little *holes* or *pores*, from which gases and other volatile parts have been driven off by *previous combustion.*

Q. Is fire-light ALWAYS of the SAME intensity?

A. No; it *varies very considerably*, depending upon the *degree of heat* to which the carbon has been raised by *combustion.*

Q. Coals BLAZE, cinders do NOT: WHY is this?

A. Cinders produce *carbonic acid only*, which does not give light; the *flame* of coal being caused by *carburetted hydrogen.*

Q. Where does the HYDROGEN GAS of a fire COME FROM?

A. It is one of the *elements of fuel* produced by the *action of the heat.*

Q. Why is it that the fire burns BRIGHTEST and CLEAREST during a FROST?

A. *Cold* air *contains more oxygen* and is *heavier* than *warm* air; the result of this is that as the *warm air* from the fire *ascends*, the *cold air* very rapidly supplies its place, the fuel is more *quickly consumed*, and the fire is thus made to burn *bright* and *clear.*

Q. ASHES or CINDERS are put over the fire to PREVENT its BURNING AWAY: can you tell the reason for thus COVERING the fire?

A. The ashes or cinders prevent the oxygen of the air from gain-

ing free access to the fire; and as fire will not burn freely without an abundant supply of *oxygen*, it keeps alive for several hours *without being wasted.*

Q. Why does RAREFIED AIR afford LESS NOURISHMENT to fire than cold air?

A. Because rarefied air contains comparatively *less* oxygen than the same volume of condensed air.

Inasmuch as the same quantity of oxygen is diffused over a larger volume of air.

Q. Why does the air flow to the fire MORE TARDILY for being RAREFIED?

A. Because the greater the contrast between the *external air* and that which has been *heated by the fire*, the more rapid will be the current of air towards the fire.

Q. How is it that WATER EXTINGUISHES a FIRE?

A. Because, by forming a covering over the fuel, it keeps it from the air, and the conversion of the water into steam carries off the heat of the fire, and gradually puts it out.

Q. Why does a LITTLE WATER makes a fire FIERCER, while a LARGER quantity of water puts it OUT?

A. Water is composed of oxygen and hydrogen; when, therefore, the fire can decompose the water into its simple elements, they serve for fuel to the flame.

Q. How can WATER serve for FUEL to fire?

A. The oxygen and hydrogen of the water being separated from each other, *unite with the carbon* to form *carbonic oxide* and *carburetted hydrogen*, both of which are inflammable.

Q. Is the quantity of heat INCREASED by the addition of a little water to a hot fire?

A. The quantity of heat given forth is *the same*, whether carbonic acid is formed by the combination of carbon and oxygen, or carbonic acid from carbon, oxygen, and the elements of water. The access of water lessens the *glow-fire*, but produces a greater quantity of flame in consequence of the formation of inflammable gases.

If a sufficiency of water is thrown on to cause, by its evaporation, a reduction of temperature below the point of combustion, the fire is put out.

Q. How do you EXPLAIN the familiar experiment of drawing a bank-note over the head of a brass andiron, or the face of a flat-iron, and placing a burning coal upon it, and blowing the coal with a bellows until it is burned up, without scorching the paper of the bank-note?

A. The metal in close contact with the paper *conducts off the heat so rapidly* from the coal, that it *prevents combustion.*

Q. Why does a blast of air from a pair of bellows often EXTINGUISH a red-hot coal of anthracite?

A. Because the cold air *absorbs the heat* of the coal so quickly that it extinguishes it.

Q. Why can you not light a candle or lamp with a match so long as the SULPHUR on the end of it is BURNING?

A. The chemical reason for this well-known fact is, that the *sulphurous acid* formed by combustion of sulphur in the air, *surrounds the wick*, and *abstracts* the *oxygen* from the air, by passing to a higher state of oxidation, and this heavy vapour hangs about the wick and excludes the air.

Q. Cannot wood be made to BLAZE WITHOUT actual CONTACT with fire?

A. Yes; if a piece of wood be held *near* the fire for a little time it will blaze, even though it does not *touch the fire.*

Q. WHY will wood BLAZE, even if it does not touch the fire?

A. Because the heat of the fire drives out the *inflammable gas* of the wood, which gas is ignited by contact with red-hot coals.

Q. What causes the HEAT of FIRE?

A. The *carbon of fuel* (when heated) combines with the oxygen of the *air*, and produces *carbonic acid gas.* Again, the *hydrogen* of the *fuel*, combining with *other portions* of oxygen, condenses *into water;* by which chemical actions *heat is evolved.*

Q. WHENCE does the HEAT of a DUNGHILL arise?

A. As the *straw, &c.*, of the *dunghill* decays, it *undergoes* fermentation, which produces *carbonic acid gas;* and heat is evolved through a species of combustion.

Q. On what does the INTENSITY of FIRE depend?

A. The *intensity* of fire is always in proportion to the *quantity of oxygen* with which it is supplied.

Q. Why does STIRRING a dull FIRE serve to quicken it?

A. Because it breaks up the compacted cinders and coals, making a passage for the air into the very *heart* of the fire.

An anthracite coal fire should be stirred from the bottom, and not from the top.

Q. Why do LAMPS SMOKE?

A. Sometimes because the wick is *cut unevenly;* sometimes because it is *raised up too high.*

Q. WHY does a LAMP SMOKE when the WICK is CUT UNEVENLY?

A. 1. Because the *points of the jagged edge* (being very easily separated from the wick) load the flame with more carbon than it can consume; and

2. As the heat of the flame is greatly diminished *by these bits of wick*, it is unable to consume *even the usual quantity of smoke.*

Q. Does a LAMP SMOKE when the WICK is TURNED UP TOO HIGH?

A. Yes; *more carbon* being separated from the wick than can be consumed *by the flame.*

Q. Why is the flame of a candle EXTINGUISHED when blown by the breath, and not made more intense, like a fire?

A. Because the flame of a candle is confined to a very small wick, from which it is *severed* by the breath, and (being unsupported) *must go out.*

Q. When a chimney with an open fireplace gets on fire, and burns so as to endanger the house, how may it at once be EXTINGUISHED?

A. By throwing a quantity of *brimstone* or *sulphur* into the fire, and *closing up the fireplace* with a fireboard or screen. The sulphurous acid soon fills the chimney, and taking up all the oxygen from the contained air, extinguishes the fire. Even the fire, after it has

extended into the woodwork of the house, may be extinguished by this simple method.

Q. Fire in a chimney may be also extinguished by closing the top of the flue with a damper : HOW does this EXTINGUISH the fire ?

A. It *cuts off the draught*, and the carbonic acid generated by the combustion soon puts an end to the fire.

Q. What is meant by SPONTANEOUS COMBUSTION ?

A. Combustion produced without *contact with fire or flame.*

Q. Give me an EXAMPLE of spontaneous combustion.

A. *Oiled cotton and rags* imbued with any drying oil, when packed in mass in a barrel, take fire, after a time, at ordinary temperatures. Mixed lampblack and linseed-oil take fire at ordinary temperatures, if the lampblack is in excess, or a portion of it is dry.

Q. What is generally the CAUSE of SPONTANEOUS COMBUSTION ?

A. The *absorption of oxygen*, which finally causes bodies to burst into a flame.

Q. Why do GOODS packed in warehouses, in large masses and in a damp state, often CATCH FIRE ?

A. Because the damp produces decay, and the great heat of the piled-up mass makes the decaying goods ferment. During fermentation great *heat* is produced by *chemical action;* a slow combustion ensues, till at length the *whole pile bursts into flame.*

Q. Why is the HEAT of a LARGE MASS of goods GREATER than that of a smaller quantity ?

A. Because the heat produced *cannot escape* through the massive pile; and the temperature of the heap is therefore considerably raised. It is thus that *haystacks* sometimes *catch fire* of themselves, either because the hay was put up damp, or else because rain has penetrated the stack.

Q. Is PINE CHARCOAL capable of TAKING FIRE at an extremely LOW TEMPERATURE ?

A. Porous bodies, like pine charcoal, when perfectly dry, *absorb* oxygen *rapidly* from the air, and take fire at a temperature below 212 degrees Fahrenheit, or the boiling-point of water.

This has been proved by actual experiment, a piece of light pine charcoal taking fire on a surface of sheet iron heated below the boiling-point of water.

Q. In what TWO WAYS is heat communicated to apartments by fires kept in them ?

A. By *radiation* and *immediate contact.*

The first portion passes through the air in diverging lines with great velocity. The second penetrates slowly through the substance of the densest bodies. To enjoy the full effect of radiated heat we must be in the presence or sight of the radiating object. To receive conducted heat we must be in contact, either directly or through some intervening medium, with the body that imparts it.

Q. Does a person who sits by a fire in the open air receive any HEAT by CONDUCTION ?

A. Very *little;* for the air which surrounds the fire, having nothing to confine it, *ascends by its diminished specific gravity* as fast as it is warmed, and its place is immediately supplied by strata of cold air from beneath.

Q. Will a person sitting BESIDE a FIRE in the open air be exposed, upon the side of his body removed from the fire, to additional cold?

A. He *will*, because cold currents *rush in from every side* towards the fire.

Q. Why are OPEN FIREPLACES ill-adapted for cheaply heating apartments?

A. In an open fireplace the air flows *from* the room *to* the fire, becomes heated, and passes off directly into the chimney, without having an opportunity of parting with its heat for any useful purpose. In addition to this, a quantity of the air of the room, which has been warmed by radiation, is uselessly carried away by the draught.

Q. What is a "REVERBERATING FURNACE?"

A. One provided with a *concave covering*, which *reverberates* or *throws back* the flame upon the substance to be heated or melted.

Q. What are the ADVANTAGES of a STOVE over an open FIREPLACE?

A. 1. Being detached from the walls of the room, the greater part of the heat produced by combustion is *saved.* The radiated heat being thrown into the walls of the stove, they become hot, and in turn *radiate heat on all sides* to the room. The conducted heat is also received by successive portions of the air of the room, which pass in contact with the stove;

2. The air being made to *pass through the fuel*, a small supply is sufficient to keep up the combustion, so that little need be taken out of the room; and

3. The smoke, in passing off by a pipe, parts with the *greater part of its heat* before it leaves the room.

Q. What are the DISADVANTAGES of stoves?

A. Houses containing them are generally *ill-ventilated.* The air coming in contact with the hot metal surfaces is rendered impure, which impurity is increased by the burning of the dust and other substances which settle upon the stove. The air is, in most cases, kept so dry as to render it oppressive.

Q. Upon WHAT PRINCIPLE are the common hot-air furnaces for warming houses constructed?

A. A *stove*, having *large radiating surfaces*, is enclosed in a chamber (generally of stone). This chamber is generally built with double walls, that it may be a better non-conductor of heat. A *current of air* from without is brought by a pipe or box, and delivered *under the stove.* A part of this air is admitted to supply the combustion; the rest passes upwards in the cavity between the hot stove and the walls of the brick chamber, and, after becoming thoroughly heated, is conducted through passages in which its lightness causes it to ascend, and be delivered in any apartment of the house.

Q. What are the ADVANTAGES of heating by steam?

A. The heat can be communicated for a great distance in *any direction*—upwards, downwards, or horizontally. As the temperature

of the heating surfaces, when low-pressure steam is used, never exceeds 212 degrees F., the air in contact with them is never contaminated by the burning of dust or the abstraction of oxygen.

Q. In heating by steam, how MUCH BOILER CAPACITY is required to heat a given space?

A. Under favourable circumstances *one cubic foot* of boiler will heat about *two thousand cubic feet* of suitably enclosed space to a temperature of 70 degrees to 80 degrees F.

Q. In the construction and arrangement of a furnace for warming, what TWO POINTS are of special IMPORTANCE, so far as regards the economy of fuel?

A. 1. The *perfect combustion* of the fuel; and

2. The best possible *transmission* of all the heat formed into the air that is to pass into the rooms of the house.

Q. How is the first of these requisites OBTAINED?

A. By having a *good draught* and a fire-box which is *broad* and *shallow*, so that the coal shall form a thin stratum; by which arrangement the carbonic acid gas will be freely formed, and pass off without a previous production of carbonic oxide.

Q. How is the second of these requisites ATTAINED?

A. By providing a *great quantity of surface* in the form of pipes, drums, or cylinders, through which the smoke and hot gases must pass on their way to the chimney, and to which their heat will be imparted, to be in turn delivered to the cold and pure air of the rooms of the house.

Q. Is DECAY a species of combustion?

A. Decay is the act of *gradual combination* of the *combustible elements of a body* with the *oxygen* of the air. It is, therefore, a species of *slow combustion.*

Q. Why do AIR-TIGHT stoves sometimes explode?

A. It frequently happens that when air-tight stoves are closed very tightly, they become filled with a mixture of *inflammable gases*, chiefly carburetted hydrogen and carbonic oxide. If we admit air into the stove when thus filled with these gases, the instant flame is produced an explosion takes place, blowing a flash of flame and ashes out of the stove, and throwing open the valve in the funnel, if it is a proper turn-valve or disc. If, on the other hand, it is a slide-valve, and the air-hole of the stove is very small, the stove is blown asunder by the explosion.

Q. Why is the use of air-tight stoves injurious to the chimneys into which they open?

A. In an air-tight stove the wood undergoes a process of distillation, and a very abundant product of this distillation is wood vinegar, or pyroligneous acid. This acid acts upon the mortar of chimneys, and gradually removes the cement from between the bricks. The mortar of new houses, not fully hardened, is most readily dissolved out by the acids from air-tight stoves. New houses that have these stoves may be often known by the colour of the bricks on the outside

of the chimneys, the oxide of iron having been dissolved out from the bricks quite through their mass.

Q. Why do not all flames give the same amount of light?

A. The light of a flame depends upon the presence of incandescent solid matter in it. Hence those gases and vapours can only become luminous which produce or deposit solid or liquid matter during their combustion.

Q. Upon what fact does the production of artificial light depend?

A. Upon the fact that at certain high temperatures all matter becomes luminous.

Q. In order that we may profitably use a combustible body for illuminating purposes, what is required of the products of the combustion?

A. That they should be able to fly off rapidly from the light-giving centre.

Q. The product of all the ordinary forms of combustion is a GAS—CARBONIC ACID: what would have been the RESULT if the product of every combustion had been a permanent solid?

A. The world would have been *buried beneath its own ashes.*

Q. Phosphorus burns in the air with a beautiful dazzling light: why can we not use this substance as an ILLUMINATING AGENT?

A. Because when phosphorus burns in the air the product of the combustion is a *solid—phosphoric acid*, which forms a cloud of white vapour, which afterwards *deposits itself* on objects near at hand *like snow.*

Q. Under what TWO DIFFERENT ASPECTS does carbon appear when in the act of combustion, as in an ordinary candle-flame?

A. When it is giving forth *heat* and *light*, it is a *solid;* but immediately after it becomes a *gas.*

Q. Why is the FLAME of an ordinary fire YELLOW?

A. Because the *heat* is *not sufficient* to render the carbon *white* hot. Increase the intensity of combustion, and the colour of the burning bodies, or the flames, rise from red to yellow, and from yellow to white.

Q. A CANDLE BURNS when lighted: explain how this is?

A. The heat of the lighted wick changes the tallow into its elementary parts, *hydrogen* and *carbon.* The hydrogen is first consumed as a gas by itself with an almost imperceptible light, but with a powerful heat: this causes the carbon produced at the same time to give out both light and heat.

Q. As more carbon is successively produced, what BECOMES of it?

A. The moment the carbon comes to the edge of the flame, it finds the oxygen of the air, *unites with it*, and becomes *changed into the invisible gas, carbonic acid*, while its place is occupied immediately by another portion of solid carbon.

Q. What if there is not SUFFICIENT OXYGEN to consume the carbon?

A. It then *passes off as soot*, and we say the candle *smokes.*

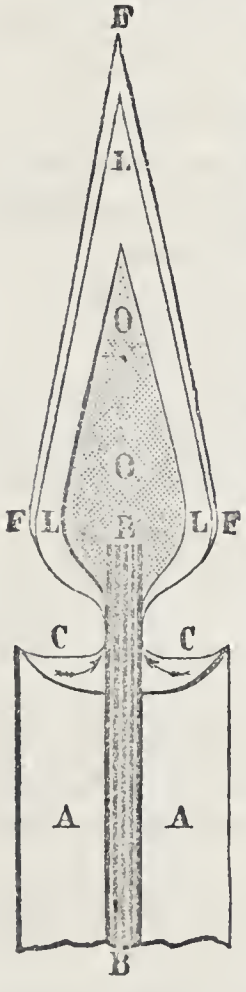
Q. When a CANDLE is BLOWN OUT, whence arises the OFFENSIVE SMELL?

A. The tallow distils a substance in the smoke called acryle, which has a very offensive smell.

Q. Of what THREE PARTS does the flame of every lamp or candle consist?

A. The flame of every lamp or candle consists of *three cones*. The innermost cone consists of gaseous matter produced by the decomposition of the tallow; this is at a temperature below redness. Around it is the luminous cone, consisting of burning hydrogen, in which the particles of carbon float at a white heat; and on the very outside, a thin, hardly-perceptible vail in which carbon is burning. The vail is of a blue colour, most plainly seen at the bottom of the flame.

Fig. 137.



The accompanying figure shows the effect of combustion in a common candle.

A A is the candle, B B the wick of the candle. C C is the cup-like bath of melted grease at the top of the candle, and around the lighted wick B B, the fibres of which, similar to small tubes, draw up the grease, and feed the flame. The flame itself, as already described, is composed of three parts—the gaseous matter, O O, the light, L L, and the outside coating, F F.

Q. Which is the HOTTEST part of the flame?

A. The *pale-blue flame;* this marks the point where the combination of the oxygen, supplied from without, with the combustible matter evolved from the interior takes place.

Q. Why is the INSIDE of the flame HOLLOW?

A. Because it is filled with vapour, raised from the candle by the *heat of the wick*, and not yet reduced to a state of combustion.

Q. Why does the FLAME of a candle POINT UPWARDS?

A. As hot air always ascends, the air heated by the candle draws up the flame.

Q. Why is the FLAME of a candle POINTED at the top like a cone?

A. As the gas constituting the flame ascends, it will continue to *diminish in diameter*, on account of the constant combustion, until it entirely disappears. The speed of this diminution, together with that of the ascent (of the current of air), gives rise to the conical shape of the flame.

Q. How is it that the FLAME of a candle can be BLOWN OUT?

A. It is parted from the wick, and goes out for want of support.

Q. Why is not the WICK of a candle CONSUMED?

A. The wick, although it is blackened by the heat, is prevented from consuming, merely because it is *surrounded by inflammable vapour*, so that the oxygen of the air has no access to it.

Q. A LONG WICK is covered with what is called a flower at the top: what does this ARISE FROM?

A. This knotty or flowery appearance arises from an *accumulation*

of charred particles of cotton, which have not been completely burnt, because the oxygen of the atmosphere has been kept from them by the outer cone of the flame.

Q. Why do COMMON CANDLES require SNUFFING ?

A. The reason why the wick of a common tallow candle requires continual snuffing is, that if it is suffered to become long, *it divides the blaze*, and *intercepts a part of the light.* It also cools the flame by its radiation, obstructs the combustion, and thus causes the escape of smoke and the deposition of carbon.

Q. Why do WAX and SPERMACETI CANDLES never require snuffing ?

A. Wax and spermaceti, being less fusible than tallow, may be burnt with a smaller wick, which, if made sufficiently slender, *bends out of the flame*, and burns off so as not to require snuffing.

The wick of *tallow* candles (on the other hand) is made of *coarse cotton*, which is too substantial to be consumed by the heat of the flame, and must be cut off by snuffers.

Q. Why are the wicks of wax and sperm candles BRAIDED or TWISTED strongly ?

A. The braiding causes a *tension* of *the fibres*, which obliges the free part of the wick to *bend considerably*, and brings the end sufficiently soon out of the flame to be *constantly reduced to ash.*

Q. Why does a candle FLICKER, especially just previous to its being BURNT OUT ?

A. Because it is unequally *supplied with combustible gases.*

When a candle is nearly burnt out, there is not sufficient tallow or wax to keep up the regular supply of combustible gas ; in consequence of which the flame *flickers*—that is, *blazes*—when it is supplied with gas, and *goes out* for a moment when the supply is defective.

Q. How does an EXTINGUISHER put out a candle ?

A. By exhausting the air round the flame.

Q. Why is the hydrogen arising from the decomposed elements of the candle mostly consumed in the MIDDLE CONE, and not upon the OUTSIDE ?

A. Because the *oxygen* of the air has a greater affinity for hydrogen than for carbon, and that which penetrates to this part of the flame, not being *sufficient* to combine with *both*, unites with *hydrogen* to form *water.*

Q. Why will not the plan of braiding the wick, adopted in sperm and wax candles, answer in the manufacture of TALLOW CANDLES ?

A. Because the bending of the wick, which causes part of the flame to project, would *melt the tallow on one side too quickly*, causing the candle to "gutter."

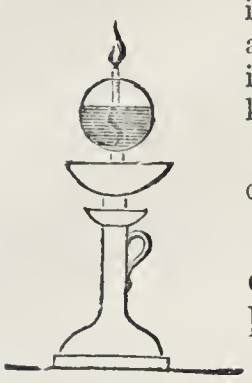
Tallow melts at a lower temperature than wax or stearine, which prevents the employment of this plan for consuming the wick.

Fig. 138.

Q. What was the most ANCIENT FORM of lamp used by the Greeks and Romans ?

A. It was simply a *cup* in which a *wick was laid*, the end of which projected from a sort of beak at the side, nearly on a level with the surface of the oil. (*See fig.* 138.)

Fig. 139.



Towards the close of the last century the pump, or spring lamp, was invented. The upper part of the lamp, seen in the diagram, is movable, and can be made to descend into the bath of oil by a spring. The oil is thus raised, and soaks the wick. By this means the oil is always kept at a proper level.

Q. Why does a lamp BURN INDIFFERENTLY if the oil in it is BELOW, or at a DISTANCE FROM, the flame?

A. Because the distance of the oil from the flame diminishes the *capillary attraction* of the wick, and the light fails through lack of illuminating material.

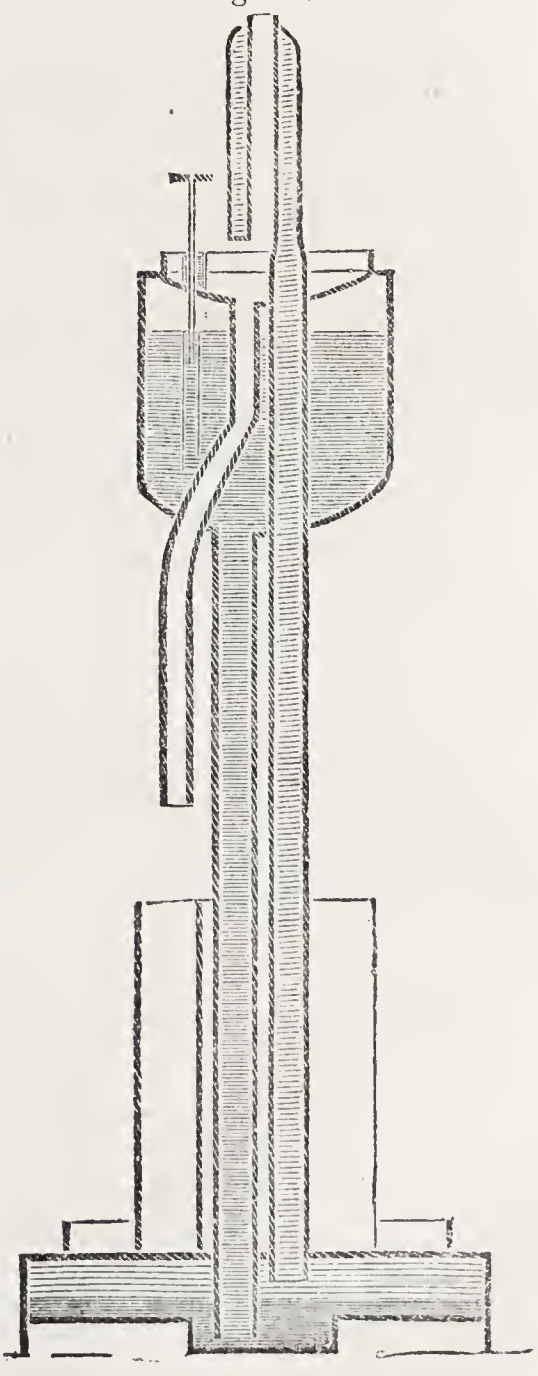
Q. Why do all closed lamps require a SMALL HOLE in the top?

A. To admit the *air;* otherwise the pressure of the atmosphere will prevent the oil from ascending the wick; if the hole be obstructed, the oil will sometimes *overflow* from the expansion of the confined air.

Q. What is a CARCEL OR MECHANICAL LAMP?

A. One in which the oil is *pumped up*, by an arrangement of *clock-work*, from the foot of the lamp to the wick, in such a manner as to supply an uninterrupted and equal quantity during the whole period of burning. (See *fig.* 140.)

Fig. 140.



Q. What is an ARGAND LAMP?

A. This name is applied, after its inventor, Argand of France, to all lamps with *hollow* or *circular wicks;* the intention of the Argand burner is to furnish a more rapid supply of air to the flame, and to afford this air to the centre as well as to the outside of the flame.

An Argand lamp consists of two metallic cylinders, one within the other; the space between them, which is closed at the base, contains the oil, and the cylindrically woven wick attached at the bottom to a movable ring; this ring is capable of being elevated or depressed by means of a screw, so that the height of the wick may be varied to regulate the size of the flame. When the lamp is lighted, and a chimney adjusted over the wick, a powerful draught is caused to pass up through the inner hollow cylinder, and the interior of the flame, and also upon the exterior; in this way a complete combustion is caused to take place, and the intensity of the light is increased.

Q. Why is a METALLIC BUTTON sometimes placed WITHIN the BLAZE, over the inner cylinder?

A. In order to *deflect the current of air* passing up the inner cylinder against the flame outward.

Q. Why do we use GROUND-GLASS globes for lamp shades?

A. To *relieve the eye* from the glare of light. Ground-glass shades have the effect of *dispersing the rays* by the numerous reflections and refractions which they occasion, until at length the light issues from all parts of their surface, and it appears as though the glass itself were the luminous body.

Q. Why are the shadows LESS DEEP and strong from a light surrounded with a ground glass, than from an open light, or one surrounded by a clear glass?

A. In the latter case the rays proceed in *direct lines*, without intermixture or crossing; but when the light proceeds from a ground glass, the rays are *so broken and refracted*, that they *cross each other in all directions*, and the objects illuminated by them can only throw short and indistinct shadows.

Q. Upon what MATHEMATICAL LAW is the measurement of the comparative illuminating power of different lights founded?

A. On the law that the amount of rays thrown on a given surface is *inversely as the square of the distance* of the illuminating body.

This law may be practically illustrated as follows:—

Place two lights which are to be compared with each other at a distance of a few feet from a white wall; on holding a small card near the wall, two shadows will be formed, the darker one by the interception of the brighter light, and the fainter shadow by the interception of the duller light. Bring the fainter light nearer to the card, or remove the brighter light farther from it, till both shadows acquire the same intensity. Measure now the distances of the two lights from the wall, and the squares of these distances will give the ratio of illumination.

Q. In what way should PICTURES be HUNG in respect to a source of illumination, as a lamp or window, so as to secure for them a good light?

A. Paintings should *not* be hung *opposite to lights*, or in any situation in which a line drawn from the place intended for spectators will make the *same angle* with the *surface* of the picture, as a line drawn from a window or other illuminating point; the angle of reflection being always equal (as already explained) to the angle of incidence.

Q. As a general rule, when will a picture be always in a BAD LIGHT as regards the spectator?

A. Whenever the *image of a window* could *be seen by him* in a *looking-glass*, occupying the same place as the picture.

Q. In what respect does a gas light DIFFER from the light of an ordinary candle?

A. In the flame of a common lamp or candle the combustible matter is not burnt until it has first been converted into *inflammable vapour or gas.* This gaseous matter is *burnt* as fast as it is formed

in consequence of being brought in contact with atmospheric air, and is set on fire by the same heat that produces it. In the case of a gas light, the inflammable gas is distilled by heat from the illuminating substances in close vessels, and conveyed in pipes to the point where the illumination is required. In the one case, the gas is formed and burnt at the same time and place; and in the other, it is formed at one place and burnt at a different time and place.

Q. From what MATERIALS is gas generally PRODUCED ?

A. In most cases from *bituminous coal;* it can, however, be readily produced from *resins*, *oils*, *fats*, *wood*, *&c.*

Q. What is COAL GAS ?

A. *Carburetted hydrogen.*

Q. What is CARBURETTED HYDROGEN GAS ?

A. Carbon combined with hydrogen. There are two kinds of carburetted hydrogen—light carburetted hydrogen, and heavy carburetted hydrogen.

Q. What is the DIFFERENCE between LIGHT carburetted hydrogen and HEAVY carburetted hydrogen ?

A. The latter contains *twice as much carbon* as the other; it is also known as *olefiant gas.* It is the common illuminating gas.

Q. What is MARSH GAS or FIRE DAMP ?

A. Light carburetted hydrogen gas accumulated on marshes, in stagnant waters, and coal pits. It is frequently called "inflammable air."

Q. WHY is light carburetted hydrogen gas called FIRE DAMP, or inflammable air ?

A. Because, when mixed with air, it *readily catches fire* and explodes when a light is brought in contact with it.

Q. How may light CARBURETTED HYDROGEN GAS be PROCURED on marshes ?

A. By stirring the mud at the bottom of any stagnant pool, and collecting the gas (as it escapes upwards) in an inverted glass vessel.

Q. What gas is given forth by the WICK of a burning CANDLE ?

A. *Heavy carburetted hydrogen gas.*

Q. What OCCASIONS the frequent EXPLOSIONS in coal mines ?

A. In most coal mines enormous quantities of *light carburetted hydrogen* are generated from the coal, and mingling with the air of the mines constitutes an *explosive mixture.* When the explosive compound is brought in contact with the flame of a lamp, ignition takes place, accompanied with the most fearful consequences.

Fig. 141.

Q. If it is, therefore, dangerous to introduce a light into a coal mine, how are the miners enabled to PROSECUTE their OPERATIONS far below the surface of the earth?

A. Sir Humphrey Davy invented a *lantern* for the use of miners, called the "*Safety Lamp*," which may be used without danger. It is a kind of lantern, covered with a fine gauze wire, instead of glass or horn, which prevents the *flame* of the lamp touching the *gas* of the mine. (*See fig.* 141.)

Q. When was coal gas FIRST USED for illuminating purposes?

A. It was first used in *England* in 1798, though it was not employed for *street illumination* in London until about 1812.

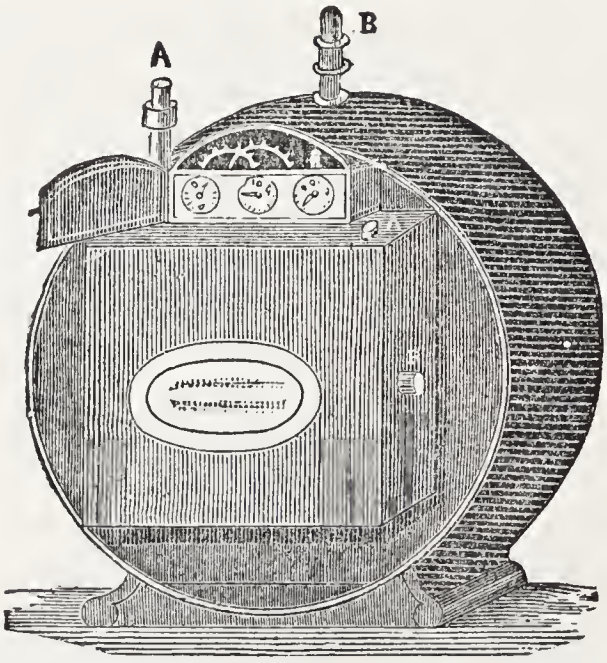
Q. What is the PROCESS of manufacturing coal gas?

A. The coal is placed in *iron retorts*, which are subjected to a *strong heat* in a furnace. The gas is thus driven off, mixed with the vapour of tar, ammonia, and of several volatile oils, and in this state is conducted by pipes, first into a horizontal trunk of cast iron called the hydraulic main, and from thence into a condensing apparatus, where the various *vapours are condensed* and *fall down*, while the gaseous product is carried away, together with several other impure gases.

Q. How is the carburetted hydrogen SEPARATED from these gaseous impurities?

A By passing it through a *mixture of lime and water*, called *milk of lime*, or over dry *slaked lime*, which absorbs the remaining impurities. When thus purified, the gas is conveyed in pipes to the gasometer.

Fig. 142.



In the above diagram is shown the appearance of a gas-meter. The gas enters at **A**, and goes out at **B**.

Q. In what respect is gas manufactured from oil SUPERIOR to gas manufactured from coal ?

A. It is *richer in carburetted hydrogen*, so that one cubic foot will afford as much light as two or three of coal gas. The latter generally contains sulphur and some other impurities, from which oil gas is free.

Q. What is the most EXPENSIVE MATERIAL for illuminating purposes ?

A. *Wax* made into candles.

Q. Although we obtain light from coal, a product of the mineral kingdom, and from fats and oils derived from animals, yet are not THESE substances PRIMARILY DERIVED from the VEGETABLE kingdom ?

A. They *are ;* coal is a *vegetable product*, and animals derive their fats and oils from the vegetable substances on which they feed.

Q. Under this view, is not EVERY PLANT an APPARATUS for the manufacture of light and heat ?

A. Every *plant* may be considered an *apparatus* for the absorption and concentration of *light and heat from the sun's rays*, and for the keeping of these forces during its passage through the subsequent stages of vegetable fuel.

Q. Who first DISCOVERED that combustion, as we generally see it, is merely the UNION of OXYGEN with a COMBUSTIBLE body ?

A. *Lavoisier*, an eminent French chemist, who was put to death during the reign of terror of the French Revolution.

Q. Before this discovery, how was combustion EXPLAINED ?

A. It was supposed that all combustible bodies contained a certain substance which was called *phlogiston*, to the presence of which was ascribed their combustibility. When a body burns, *phlogiston* was supposed to escape from it ; and when a body had *lost* phlogiston, it became incombustible, or a burnt body.

Q. The advocates of this theory supposed that when a body was burned, something went OUT of it : how did Lavoisier OVERTHROW this supposition ?

A. He *weighed* the body before combustion, and all the products of combustion afterwards, and found that, instead of the body *losing weight*, *it gained ;* this gain being exactly equal to the amount of oxygen it had absorbed from the air.

SECTION II.—RESPIRATION.

Q. What is RESPIRATION ?

A. The act of *inhaling air* into the lungs, and again *expelling it.*

Q. What is the OBJECT of drawing air into the lungs, and again expelling it ?

A. To *oxidise* the carbon and hydrogen of the blood.

Q. We receive into the lungs oxygen through the medium of the atmosphere, mingled with nitrogen : WHAT do we EXPEL from the lungs ?

A. The *nitrogen* returns unaltered ; the *oxygen* unites with the *carbon* of the blood to form a gas—*carbonic acid*, and with *hydrogen* to form the *vapour of water.*

Q. Are not these the SAME PRODUCTS of every ordinary form of COMBUSTION ?

A. They *are ;* therefore *respiration* or *breathing* is but a form of *combustion.*

Q. It is estimated that a man receives into his system about eight hundred pounds of oxygen from the atmosphere in a year, but his WEIGHT at the end of the year has increased but LITTLE, or NOT AT ALL : what BECOMES of all this oxygen ?

A. No part of it remains in the body, but it is *given out again*, combined with carbon and hydrogen.

Q. How MUCH carbon passes out of the system of an adult man by the agency of respiration daily ?

A. About *three pounds.*

Q. How is this great ABSTRACTION of material from the body MADE UP ?

A. By the *food* which we eat.

Q. Are the organs by which respiration is performed the SAME in all animals ?

A. The organs of respiration *differ essentially* in the various divisions and in the various subdivisions of the animal world.

Q. In what manner do the LOWEST TYPES of the animal kingdom, as the polypes, or coral-building animals, respire ?

A. Exclusively *through the skin.*

Q. Does man also respire, or absorb and expel oxygen and carbonic acid, in a degree THROUGH the SKIN ?

A. He *does;* and this explains the fact that *extensive burns* on the surface of the body frequently produce *diseases of the lungs.*

Q. Why should extensive burns on the surface of the body tend to produce DISEASES of the LUNGS ?

A. While in a condition of health, the skin aids the lungs in the expulsion of *carbonic acid* from the body; but the portion of the skin which has been scorched by an extensive burn, no longer being able to perform that function, the lungs are obliged to assume an *extra duty*, and suffer as a consequence of their exertion.

Q. If, by NEGLECT of WASHING, we suffer the skin to become covered with impurities, do we not disturb the healthy action of the system ?

A. We *do;* there is no better-established law of health, than that the surface of the whole body should be *kept clean* and free from all impurities.

Q. What ANIMALS are provided with LUNGS ?

A. Lungs are for the most part confined to animals that are possessed of *vertebra* or a *back bone.* Some animals, however, such as spiders and some species of snails, which are *destitute of a back bone*, have, nevertheless, *regular lungs.*

Q. How do INSECTS BREATHE ?

A. By means of organs called *tracheæ* or *windpipes*—tubes which penetrate in various directions through their bodies, and terminate externally in open orifices called *stigmata.*

Q. Why, if we cover an insect with OIL, does it speedily DIE ?

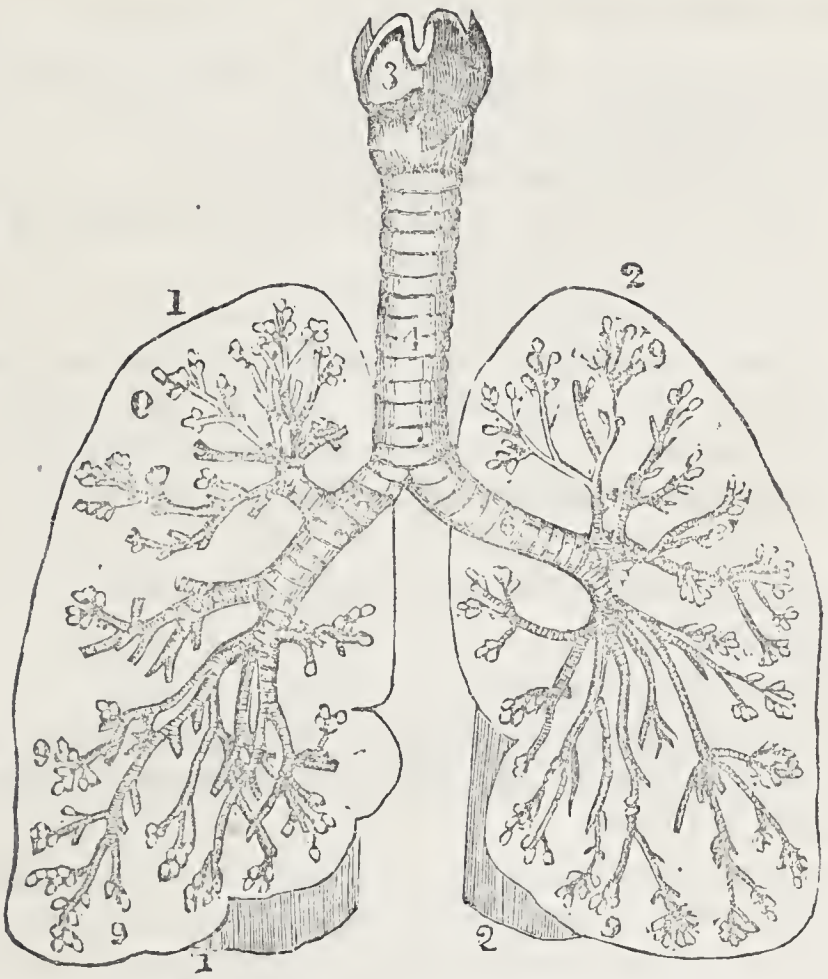
A. Because the oil *fills up the stigmata*, respiration is suspended, and the insect dies of suffocation.

Q. What are the LUNGS?

A. Lungs are made up of *blood vessels* imbedded in a fleshy substance which we denominate *cellular tissue*, and expanded over the walls of a series of chambers or cavities.

The organs of respiration are the lungs (lights), the trachea (windpipe), the bronchia (subdivision of the trachea), and the air-cells, or, as they are called, air vesicles.

Fig. 143.



Representation of the larynx, trachea, bronchia, and air-cells.—1, 1, 1, an outline of the right lung; 2, 2, 2, an outline of the left lung; 3, the larynx; 4, the trachea; 5, the right bronchial tube; 6, the left bronchial tube; 7, 7, 7, 8, 8, 8, bronchial tubes of right and left lung; 9, 9, 9, 9, 9, 9, air-cells.

Q. To what may the MECHANISM of the lungs in respiration be COMPARED?

A. To the *action of a bellows.*

Q. In what respect do the gills of fishes differ from the LUNGS of land animals?

A. Gills are a *variety of lungs*, but in them the blood vessels are freed from all covering, and hang loosely in the form of a fringe, floating on the water; this form of lungs is best adapted for the extraction of the oxygen dissolved in the water.

Q. If the carbon taken from the system through the agency of the lungs be not restored, what is the CONSEQUENCE?

A. *Starvation ensues.*

Q. Does a person whose respiration is RAPID and ACTIVE, require MORE FOOD than one whose respiration is sluggish?

A. Two persons, who in equal times take up by means of the lungs

and skin *unequal quantities of oxygen*, require in the same ratio *unequal quantities of nourishment.*

Q. A BIRD deprived of food dies on the THIRD day, while a SERPENT will live without food for THREE MONTHS or more : what is the reason of this ?

A. A bird *breathes quickly*, and rapidly consumes the carbon of its system, while the respiration of a serpent is *very sluggish;* consequently, the carbon of its system is *wasted slowly.*

Q. Why does a CHILD require FOOD OFTENER than an ADULT, and bear hunger less easily ?

A. Because the organs of respiration in a child are *more active* than those of a grown person.

Q. How does the OXYGEN we inhale MINGLE with the BLOOD ?

A. The oxygen of the air is taken into the lungs by the *blood*, which gives to it a bright red colour.

Q. How does OXYGEN convert the colour of blood into a BRIGHT RED ?

A. The *colouring* matter of the blood is formed by very *minute globules* floating in it. The oxygen uniting with these globules changes their colour to a *bright red.* The blood contains *iron*, and this metal is supposed to play an important part in the colouration of the blood.

Q. What COLOUR is the blood BEFORE this change takes place ?

A. A *dark purple.*

Q. Do PLANTS RESPIRE as well as animals ?

A. They *do;* and their leaves may be regarded as performing for them *similar offices as the lungs of animals.* They are the breathing organs of plants.

Q. Is there any DIFFERENCE between the respiration of plants and animals ?

A. The process of respiration in plants is exactly the *reverse* of that in animals. Animals *absorb oxygen*, and *give out carbonic acid;* plants, on the contrary, *absorb carbonic acid*, and *return oxygen.*

Q. It is estimated that the population of London adds to the atmosphere daily 4,500,000 pounds of carbonic acid : how is this immense quantity of deleterious gas REMOVED from the atmosphere ?

A. Principally through the agency of *plants*, which absorb it.

"The carbonic acid with which to-day our breathing fills the air, to-morrow seeks its way round the world. The date trees that grow round the falls of the Nile will drink it in by their leaves ; the cedars of Lebanon will take of it to add to their stature ; the cocoa-nut of Tahiti will grow rapidly upon it ; and the palms and bananas of Japan will change it into flowers. The oxygen we are breathing was distilled for us some short time ago by the forests of the Susquehanna, and the great trees that skirt the Orinoco and the Amazon ; the giant rhododendrons of the Himalayas contributed to it, and the roses and myrtles of Cashmere, the cinnamon-tree of Ceylon, and the forest, older than the flood, buried deep in the heart of Africa, far behind the Mountains of the Moon."

Q. Is ANIMAL LIFE dependent on that of VEGETABLES ?

A. Yes ; animals *require oxygen*, and plants *carbonic acid*, to keep them alive. Plants give forth oxygen, which supplies the necessity of the animal creation ; animals breathe out carbonic acid, which plants require. Thus the two great kingdoms—that of the animal

and that of the vegetable world—are bound in a close alliance, and made dependent upon each other.

Q. Do plants DECOMPOSE CARBONIC ACID in the NIGHT-TIME as well as during the day?

A. Plants require the influence of *light* to enable them to decompose the carbonic acid and liberate the oxygen. During the night, plants breathe carbonic acid, as before, but they return it, for the most part, again to the atmosphere, unchanged.

Q. Do WATER-PLANTS purify and free water from carbonic acid in the same manner that land-plants purify the atmosphere?

A. The respiration of fishes produces *carbonic acid*, and unless this is removed from the water, *animal life* will *cease to exist* in it. Water-plants absorb the carbonic acid from the water, and restore the oxygen.

Q. During bright weather, the leaves of water-plants, it will be noticed, are covered with LITTLE BUBBLES: WHAT are these bubbles?

A. *Oxygen gas*, liberated by the organs of the plant.

Q. Is it good policy, in fountains and reservoirs of water, to free them WHOLLY from the PRESENCE of VEGETABLE and ANIMAL organisms?

A. It is *not:* they are both *dependent on one another*, and the joint action of the two serves to keep the water pure and wholesome.

Q. Why is vegetation SO MUCH MORE VIGOROUS and LUXURIANT in the TROPICS than in the TEMPERATE ZONES?

A. In the tropics, the light of the sun is *long-continued* and brilliant. Plants are dependent upon light for their power of storing up carbon derived from the atmosphere; consequently, in those places where the action of light is most *intense*, the growth and increase of vegetation will be the *greatest.*

Q. Why do tropical plants, transported to northern climates and reared in greenhouses, always LANGUISH and INCREASE SLOWLY?

A. Because they require the full, *strong light of their native habitats.* We can impart to them the necessary heat and moisture, but the action of the light cannot be imitated.

Q. Do plants obtain CARBONIC ACID from any OTHER source than the atmosphere through their leaves?

A. They obtain considerable quantities from the *soil.*

Q. Do plants absorb any OTHER SUBSTANCES from the atmosphere, or from the soil, besides carbon?

A. They *do:* they are enabled to *decompose water*, retaining the *hydrogen* and liberating the *oxygen;* they also absorb *ammonia*, more or less of which substance is always present in the atmosphere and in rain-water.

Q. Animals, and the various forms of combustion, are continually producing large quantities of carbonic acid; all vegetation is continually liberating oxygen: does there appear to be any INCREASE or DIMINUTION of these substances in the atmosphere?

A. There appears to be an *exact balance or equilibrium* kept up between the animal and vegetable world, and we have no reason to believe that the great mass of the atmosphere ever changes its composition.

SECTION III.—NUTRITION AND ANIMAL HEAT.

Q. What is HEALTH in the animal body?

A. Health, in the animal body, consists in the *due balance or equilibrium* between the *oxidising or destructive agency* of the atmosphere, and the process of *nutrition*, or feeding, by which the waste is made up.

Q. What is the CAUSE of animal heat?

A. The *oxygen* of the atmosphere, received into the blood in the lungs, and *circulated throughout every part of the animal body*, acting upon the *food*, is the chief source of animal heat.

Q. Why does OXYGEN received into the BLOOD produce HEAT?

A. Through the medium of the *capillary vessels*, oxygen absorbed from the atmosphere unites with carbon and hydrogen. This union is a species of combustion, and produces heat in the same manner as when oxygen unites with fuel in an ordinary fire.

Q. What are the CAPILLARY VESSELS?

A. The capillary vessels form a fine network all over the body. They cannot be discovered without the aid of a microscope, and the finest needle cannot be introduced beneath the skin without wounding some of them.

Q. Does this COMBUSTION, and the consequent production of ANIMAL HEAT, take place in EVERY PART of the body?

A. In the animal body, heat is produced only in those parts to which *arterial blood*, and with it the *oxygen* absorbed in respiration, IS *conveyed.*

Q. Why is there NO HEAT developed in hair, wool, and feathers?

A. Because they receive no *arterial blood*, and therefore in them no heat is developed.

Q. What TWO KINDS of blood are there in the animal body?

A. *Arterial blood* and *venous blood.*

Q. What is the DIFFERENCE between the two?

A. The arterial blood going from the lungs *conveys the oxygen* which it has absorbed in the lungs *to the capillary vessels.* In these the combustion takes place, and the colour of the blood changes from a bright to a dark red colour.

Q. What BECOMES of the blood after it has given up its oxygen to the hydrogen and carbon in the capillary vessels?

A. It enters the *veins*, carrying with it the products of combustion. The venous blood passes to the lungs, throws off the products of combustion, absorbs more oxygen, becomes converted into arterial blood with a renewal of colour, and is again returned into the system.

Q. What BECOMES of the CARBONIC ACID GAS formed in the human blood?

A. The *lungs throw off* almost all of it *into the air* by the act of *respiration* or *breathing.*

Q. Is the HEAT of the HUMAN BODY the SAME as the heat of a FIRE?

A. It arises from the same cause,—namely, the *carbon of the blood* combining with the *oxygen of the air drawn in by the breath*, and producing *carbonic acid gas.*

Q. Does the carbon of the food, converted into carbonic acid in the body, give out as MUCH HEAT as if it had been directly burnt in oxygen gas, or in common air?

A. The quantity produced is *the same;* the only difference is, the *production of the heat* is diffused over unequal times. In oxygen gas the combustion of carbon is rapid, and the heat intense; in atmospheric air it burns slower and for a longer time, the temperature being lower; in the animal body the combustion is still more gradual, and the heat is lower in proportion.

Q. If the HEAT of the HUMAN BODY is the SAME as the HEAT of a FIRE, how is it the human body is not burnt up?

A. It is; every portion of the human body wastes as a fire does; and as the fire would go out if *fuel* were not added, so the human body would be destroyed if *food*, the *fuel of the body*, were not supplied.

Q. Why does FLANNEL, &c., make us WARM?

A. Flannel and warm clothing do not *make* us warm, but merely prevent our body from becoming cold.

Q. How does FLANNEL, &c., prevent our body from becoming cold?

A. Flannel (being a bad conductor) will neither carry off the heat of our body into the *cold air*, nor suffer the cold of the air to come in contact with our warm body; and thus it is that flannel clothing keeps us warm.

Q. Why are FROGS and FISHES COLD-BLOODED animals?

A. Because as they *consume* very little air, combustion is too slow to produce much animal heat. All animals, strictly speaking, are warm-blooded; but in those only which possess lungs is the temperature of the body quite independent of the surrounding medium.

Q. In WHAT ANIMALS is the temperature the greatest?

A. Those animals which *respire frequently*, and consequently consume much oxygen, possess a higher temperature than others, which, with a body of equal size to be heated, take into the system less oxygen.

Q. Why is the temperature of the body of a child HIGHER than that of a man?

A. Because a child *consumes proportionally more oxygen*, and respires more frequently, than a grown-up person.

Q. Why do we PERSPIRE when very hot?

A. The pores of the body are like the safety-valves of a steam-engine; when the heat of the body is very great, some of the com-

bustible matter of the blood is *thrown off* in perspiration, and the heat of the body is thereby reduced.

Q. What is the MEAN TEMPERATURE of the human body?

A. In a healthy adult it is about 99 degrees F.; the temperature of a healthy child is somewhat higher, 102 degrees F.; the temperature of birds is from 104 degrees to 105 degrees F.

Q. Why, in fattening animals, do we compel them to REMAIN INACTIVE, by confining them in stalls and pens?

A. In order that the food which they consume may not be *burnt up*, but retained and stored in the system as *fat and muscle.* Want of exercise, induced by their confinement, causes the animal to absorb but little oxygen; consequently, the system does not waste.

Q. Why is the flesh of WILD animals generally devoid of FAT?

A. Wild animals *exercise much*, and the food they consume is employed in repairing the waste of the system consequent on their activity.

Q. Why do we feel LAZY, and averse to activity, in very hot weather?

A. Because muscular activity *increases the heat* of our body by *quickening respiration;* and

2. The *food* we eat in hot weather (not being *greasy*) naturally *abates our desire for bodily activity.*

Q. How much MORE CARBON do we throw off from the system by respiration in winter than in summer?

A. Full *one-eighth more.*

Q. Why is it easier to bear hunger for a longer time at the EQUATOR than in COLD COUNTRIES?

A. As the *quantity of oxygen* introduced into the system varies with the *temperature of the external air*, the system *wastes less rapidly* from respiration in warm countries than in cold; consequently, there being less waste, less food is required in the one situation than in the other.

The temperature of the air at the equator being elevated, the temperature of the system does not diminish; consequently, food is not required in great quantity for the production of animal heat.

Q. Why do the animals of the ARCTIC regions require more food than those of the torrid zones?

A. In consequence of the cold atmosphere with which the former are surrounded, they *inspire an increased amount of oxygen*, and the necessity for food containing carbon and hydrogen increases in the same ratio.

Food being the fuel of the animal body, by consuming large quantities, they obtain the most efficient protection against the piercing cold.

Q. Is WARM CLOTHING in winter an EQUIVALENT for a certain amount of food?

A. The *more warmly* we are clothed, the *less urgent* becomes the *appetite for food*, because the loss of heat by cooling, and consequently the amount of heat to be supplied by the food, is diminished.

Q. Why are persons whose lungs, or digestive organs, are impaired, BENEFITED by a residence in a SOUTHERN CLIMATE?

A. Because by a removal to a warm country the amount of inspired oxygen *is diminished* in so great a proportion that the diseased organs have sufficient power to *supply the wants of the system*, and are not overtaxed to perform their labour; hence an opportunity is afforded for recruiting, and an improvement in health follows.

Q. Does a CARNIVOROUS, or FLESH-EATING animal, as a dog or cat, PERSPIRE?

A. They do *not;* their skin is *destitute of perspiratory pores.* They consequently require less food for their support than animals which feed on vegetable substances, and which perspire freely.

Q. Into what TWO great DIVISIONS may all the substances which man uses for food be divided?

A. Into those which are devoted to the *repair and nutriment of the body*, and those whose duty it is to furnish *animal heat by their combustion in the blood.*

Q. What SUBSTANCES are adapted to furnish the body with materials for the formation of muscles, nerves, brain, &c.?

A. Only those which contain *nitrogen*, such as animal flesh, and those grains and fruits which contain this element in their composition.

Q. What SUBSTANCES supply materials for producing animal heat by their combustion?

A. Those rich in carbon and hydrogen; as *sugar*, *fats*, *starch*, *wine*, *beer*, and *spirits.*

Q. Could LIFE be sustained for any great length of time by using as food only those substances, like fats and sugar, which are DESTITUTE of NITROGEN?

A. Those substances only are capable of being employed in the *renewal* and repair of the body, which have the *same chemical composition* as the body itself.

The experiment has been tried of feeding dogs exclusively upon substances destitute of nitrogen; starvation, within a limited period, was the result.

Q. What is SLEEP?

A. Sleep is a natural and healthy *suspension* of the *intellectual functions of the brain.*

Q. Why is the action of the senses, such as hearing, seeing, feeling, &c., SUSPENDED during sleep?

A. Because the *nerves* of *sensation* are *inactive and at rest.*

Some of the phenomena of dreaming seem to show that the functions of the organs of sense are performed in sleep; the power of perception residing in the brain being, however, dormant, the intelligence conveyed by the nerves is not recognised.

Q. Why is sleep NECESSARY for the healthy existence of the body?

A. During our waking moments, the *vital force is expended* in producing mechanical effects, as the labour of different kinds which we perform. During sleep, all labour of the body or the brain is suspended, and the vital force is employed in the *formation of new parts*, or in the *repair of those which have been wasted.* Sleep, therefore, is necessary to restore the equilibrium of the system.

Q. Why is it necessary that an infant should sleep the GREATER PART of the time?

A. In order that the vital force may be employed *almost exclusively* in building up and strengthening the system, and not be expended in producing mechanical action.

CHAPTER XLIX.

PHOSPHORUS AND SULPHUR.

SECTION I.—PHOSPHORUS.

Q. What is PHOSPHORUS?

A. *Phosphorus* is a substance resembling wax, and of a *pale yellow colour.*

Q. What is the MEANING of the word phosphorus?

A. The term is derived from the Greek, and means both to *produce* and *to carry light.*

Q. How is phosphorus COMMONLY OBTAINED?

A. From *bones*, which are heated to a *white heat*, destroying both animal matter and charcoal, leaving behind what is called *phosphate of lime.*

Q. What is the PHOSPHATE of LIME?

A. *Phosphorus united to oxygen and lime;* when this substance is treated with sulphuric acid, and the product mixed with charcoal and heated, phosphorus separates as a product of distillation.

Q. Is phosphorus INFLAMMABLE?

A. It is so exceedingly inflammable that it sometimes *takes fire* by the heat of the hand; it therefore requires great care in its management, as a *blow or a hard rub* will often ignite it.

Q. Why will FRICTION MATCHES IGNITE by merely drawing them across any ROUGH SURFACE?

A. Because the *phósphorus* with which they are tipped has a great *affinity for oxygen at a low temperature;* so that the little additional heat caused by the friction of the match across a rough surface is sufficient to ignite it, and at the same time to ignite the sulphur which is combined with it.

Q. How is phosphorus PRESERVED in its pure state?

A. Phosphorus, in its pure state, must be kept and handled *under water.* It inflames in the air with great readiness, and the combustion produced by it is difficult to extinguish.

Q. Is phosphorus a POISON?

A. Phosphorus is an *exceedingly violent poison;* mixed with dough, it constitutes a poison much used for the destruction of rats and other vermin.

Q. What is the composition with which matches are TIPPED ?

A. $1\frac{3}{4}$ parts of phosphorus, 4 of gum arabic, 4 of water, 2 of nitre, and 2 of red lead. The ends of the matches are previously covered with sulphur.

Q. Why is NITRE and RED LEAD used ?

A. Both of these substances contain a large amount of oxygen, which the phosphorus abstracts at the moment of ignition; they therefore serve to increase the intensity of the combustion.

Q. What is PHOSPHURETTED HYDROGEN ?

A. Phosphuretted hydrogen is the *gas* formed by the union of *phosphorus and hydrogen;* it possesses a very disagreeable smell, is inflammable and destructive of animal life.

Q. Under what circumstances does phosphuretted hydrogen OCCUR in NATURE ?

A. It is formed by the *putrefaction of animal substances.* Carburetted hydrogen is formed by the decay of vegetable substances. The very offensive smell of a dead body arises in part from the phosphuretted hydrogen.

Q. What is PHOSPHORIC ACID ?

A. A compound of *phosphorus and oxygen.* United with lime, it forms the bones which constitute the framework of the animal body.

Q. Does phosphate of lime ALONE compose the structure of bone ?

A. Bones consist of about *one-third organic matter—gelatine or glue*, and two-thirds inorganic matter—*phosphate of lime.* It is the presence of gelatine in the bones which renders them supple and not liable to be easily broken.

Q. Why are the bones of old people FRAGILE and EASILY BROKEN ?

A. Because they are *dry* and *wanting in gelatine.*

Q. How does phosphorus FIND ITS WAY into the SYSTEM ?

A. It exists as phosphoric acid *in the food* we consume, especially in what are called the *cereals*—corn, wheat, barley, &c.

Q. How does phosphorus, in the form of phosphoric acid, FIND ITS WAY into the system of the GRAIN-BEARING PLANTS ?

A. It is *absorbed from the soil*, in which it exists in a limited quantity.

SECTION II.—SULPHUR.

Q. What is SULPHUR ?

A. Sulphur is a *yellow, brittle mineral*, without taste, but emitting a *peculiar odour* when rubbed or heated.

Q. In what STATE does it occur in nature ?

A. It is found pure in large quantities in the vicinity of *volcanoes;* it occurs abundantly in combination with many metals, as silver, copper, lead, and iron; and is also a constituent, in small quantities, of many *animal and vegetable substances.*

Q. Why has sulphur NO TASTE ?

A. Because it is not *soluble in water.*

Q. What are the FLOWERS of SULPHUR ?

A. When the metals or earth containing sulphur, or crude sulphur, are heated, the sulphur *volatilises*, and, on cooling, is deposited from a vaporous condition as a fine *yellow powder.* This powder has received the name of "flowers of sulphur."

Q. What is BRIMSTONE ?

A. *Melted flowers of sulphur.* When the sulphur is melted and poured into cylinders or tubes, it cools in the form of rolls, and has received the name of "*roll brimstone.*"

Q. From WHAT COUNTRIES is the supply of sulphur for commercial purposes chiefly derived ?

A. From *Naples*, *Sicily*, and *Southern Italy.* From these districts large quantities are exported yearly.

Q. Why does the WHITE of an EGG tarnish a SILVER spoon ?

A. Because it contains a *little sulphur*, which, at the temperature of an egg just boiled, will decompose the water or moisture upon the spoon and produce *sulphuretted hydrogen gas*, which will tarnish silver.

Both the white and the yolk contain sulphur, but the latter the most abundantly.

Q. What is SULPHURETTED HYDROGEN ?

A. A *gas* formed by the union of *sulphur and hydrogen.* It possesses an offensive odour, and is very poisonous.

Q. How is sulphuretted hydrogen FORMED in NATURE ?

A. Principally from the *decomposition of animal substances*, as blood, flesh, hair, &c.; also from the decomposition of such vegetables as contain sulphur.

Q. What VEGETABLES especially CONTAIN SULPHUR as an element of composition ?

A. *Peas*, *beans*, *lentils*, *horse-radish*, *and onions.*

Q. What is it that makes an OPEN or FOUL SEWER so destructive of health to any district in which it may be situated ?

A. The evolution of *sulphuretted hydrogen.* When inhaled, it acts directly upon the blood, thickening it, and turning it black.

Q. Why do surfaces painted with lead paints, in the vicinity of sewers, soon turn black, or become discoloured ?

A. Through the presence of *sulphuretted hydrogen.* The sulphur unites with the lead to form sulphuret of lead, which is of a dark colour.

Q. Why do ZINC paints in the same situations continue WHITE ?

A. The *sulphur unites with the zinc* in the same manner as with the lead, but the sulphuret of zinc is white, and not dark like the sulphuret of lead.

Q. When sulphur is burned in the air, what is the PRODUCT formed ?

A. *Sulphurous acid.*

Q. Why does a RED ROSE exposed to the fumes of burning sulphur turn WHITE?

A. Through the *bleaching action* of the sulphurous acid gas generated.

Q. Is the colour of the rose entirely DESTROYED?

A. It is *not;* the colouring principle may be again restored by immersing the rose in a weak solution of *acid* or *alkali.*

Q. How are STRAW BONNETS and HATS BLEACHED?

A. By exposing them to the *fumes of burning sulphur.*

Q. What causes the SUFFOCATING SMELL of a lighted brimstone match?

A. The *sulphurous acid* generated by the combustion of the sulphur.

Q. What is sulphuric acid or OIL of VITRIOL?

A. It is a compound of *sulphur and oxygen*, containing one-third more oxygen than sulphurous acid.

Q. What are the PROPERTIES of sulphuric acid?

A. As sold in commerce, sulphuric acid is a *dense*, *oily liquid*, of a *brownish colour*, emitting white vapours when exposed to the air. It is one of the most powerful acids and agents known in chemistry, and chars and destroys most animal and vegetable substances.

Q. Why does a piece of wood introduced into sulphuric acid become BLACK and reduced to COAL, as if it had been exposed to the flame of a lamp?

A. The *sulphuric acid* seizes upon the *oxygen and hydrogen* of the wood, which combine to form water, and the carbon is left behind.

Q. What is the principal part of the sulphur of commerce USED FOR?

A. The formation and *manufacture* of *sulphuric acid.*

Q. What occasions the great DEMAND and consumption of sulphuric acid?

A. It is used in *bleaching;* in the *refining of gold and silver;* for the manufacture of *soda*, *nitric acid*, *stearine;* the *purification of oils;* for the *cleaning of iron;* the preparation of *phosphorus*, *chlorine*, *hydrogen*, *carbonic acid*, and for many other purposes. It is able to expel and drive out all other acids from their combinations.

Q. In the so-called sulphur springs, WHAT IS IT that gives to the waters their peculiar nauseating odour and flavour?

A. *Sulphuretted hydrogen*, in most instances.

CHAPTER L.

CHLORINE, IODINE, FLUORINE, SILICIUM, BORON.

SECTION I.—CHLORINE.

Q. What is CHLORINE?

A. It is a *yellowish-green coloured gas*, possessing a most disagreeable odour, and producing suffocation and great irritation of the throat and lungs, even when inhaled sparingly.

Q. Does chlorine exist in a FREE STATE in nature?

A. Chlorine is *not* found free in nature; but, *united to other elements*, is a large constituent of many organic and inorganic substances.

Q. In what FAMILIAR SUBSTANCE does chlorine especially abound?

A. In *common salt*, which is a compound of chlorine and sodium.

Q. What is MURIATIC, or, more properly, HYDROCHLORIC ACID?

A. A compound of *hydrogen and chlorine* usually prepared from salt. It is an acid much used in the arts.

Q. What REMARKABLE PROPERTY does chlorine possess, which renders it especially useful in the arts?

A. It *bleaches and destroys all colours* derived from the animal and vegetable kingdoms.

Q. When a colour is removed by chlorine, can it be RESTORED again, as is the case in bleaching by sulphurous acid?

A. *No;* the colour is permanently destroyed, and can never be restored again.

Q. How does chlorine act as a DISINFECTING agent?

A. It not only destroys all colours, but it unites to and removes all the products generated by the *decomposition* and *decay* of *animal* and *vegetable substances.*

Q. In WHAT FORM do we use chlorine for bleaching or for disinfecting purposes?

A. Chlorine is a *gas*, troublesome to make, and dangerous to employ in its pure state. It, however, forms with lime and oxygen a compound, from which it is slowly disengaged when brought in contact with air or water. This compound is known in commerce as *chloride of lime*, or bleaching powder.

Q. When INFECTIOUS DISEASES prevail, how can the contagious matter be REMOVED from bed-rooms, hospitals, houses, &c.?

A. By using a *solution of chlorine* or of sulphurous acid, which will not only remove the contagious matter, but also the offensive odour of a sick-room.

Q. What is the PROCESS of bleaching cotton and linen cloths?

A. It mainly consists in *immersing* or steeping the goods *in water* containing chloride of lime dissolved in it.

Q. Before chlorine was discovered, or its properties made known, how was the BLEACHING of fabrics EFFECTED?

A. By *moistening them with water*, and exposing them for a long period of time upon the *grass* to the *influence of the sun* and the weather. This process was called "grass-bleaching."

Q. Can you EXPLAIN how it is that chlorine is enabled to destroy all colouring materials and all noxious and offensive odours?

A. Chlorine has a *great affinity for hydrogen*, and very readily unites with it to form hydrochloric acid. All animal and vegetable substances contain hydrogen, which is taken from them by chlorine. But if a single chemical pillar falls, the whole chemical structure tumbles with it. By the abstraction of the hydrogen, the colouring matter becomes colourless, the odorous principle scentless, the infectious matter harmless, and insoluble substances are frequently rendered soluble.

Q. How was bleaching EFFECTED by exposing fabrics to the action of the weather?

A. The *oxygen of the air* played the *same part* as the *chlorine* does; it united to the hydrogen of the colouring materials and formed water. In this action, the chemical influence of the sun's rays greatly assist.

Q. What REMARKABLE PROPERTY has common salt, as regards its solubility?

A. Common salt has the remarkable property of being *equally soluble in hot and cold water.* A larger quantity of almost all other salts is dissolved by hot than by cold water.

Q. What is "ROCK SALT?"

A. Salt which is *obtained from the earth.* In England, Poland, Austria, and other countries, rock salt in great purity is found in the earth in immense beds, from whence it is quarried or dug out, as coal or other minerals are.

Q. What is "BAY SALT?"

A. Salt formed by the *evaporation of sea water*, exposed in shallow tanks to the heat of the sun. A pound of sea-water contains about one-half to five-eighths of an ounce of common salt.

SECTION II.—IODINE AND FLUORINE.

Q. What is IODINE?

A. Iodine is *a dark resplendent-looking solid* of a *bluish-black colour.* As an article of commerce it has the form of crystalline scales. When heated, it evolves beautiful violet-coloured fumes.

Q. WHEN was iodine DISCOVERED?

A. In 1812, by *M. Courtois*, a manufacturer of saltpetre at Paris. In boiling soda prepared from the ashes of sea-weeds, he noticed that under certain circumstances his kettles were powerfully corroded, and an investigation into the cause of this corrosion led to the discovery of iodine.

Q. Under WHAT CIRCUMSTANCES does iodine occur in nature?

A. It is very widely, though sparingly, distributed in nature. Its great source is *sea water*, of which *it is always a constituent.* It also exists in sea animals and plants, as in the oyster, sponge, and the common forms of sea-weed.

Q. How is iodine PREPARED?

A. The iodine of commerce is prepared from the *ashes of seaweeds*, called *kelp*, which are procured in large quantities on the coasts of Scotland, Ireland, and the Hebrides Islands. By crystallisation, treating with sulphuric acid, and heating, the iodine volatilises in a pure state, and is collected in receivers and cooled.

Q. For what PURPOSES is iodine principally employed?

A. It is extensively used in *medicine*, and is an important agent in *photographic operations.*

Q. What is FLUORINE?

A. Fluorine is an *elementary substance* which has *never been seen* in its *pure state.* It forms with hydrogen a gas, which is known as hydrofluoric acid gas. This gas can be condensed to a liquid—hydrofluoric acid.

Q. Why cannot fluorine be procured in a PURE STATE?

A. Because it *unites*, as soon as prepared, with whatever body it comes in *contact.*

Q. What are the PROPERTIES of hydrofluoric acid?

A. Of all known substances, this is the most *destructive of animal matter.* When a drop of the concentrated acid of the size of a pin's head comes in contact with the skin, instant disorganisation ensues, and a deep ulceration of a very bad character is produced.

Q. Of what are the well-known ORNAMENTS known as Derbyshire spar COMPOSED?

A. Of *fluorine united with calcium*, the basis of lime. Fluorine exists in nature chiefly in this compound, which is known as "fluor spar."

SECTION III.—SILICIUM AND BORON.

Q. What is SILICIUM?

A. An *elementary or simple body*, little known in its pure state, but united with oxygen it constitutes a *large part of the structure of the globe.* The compound formed from the union of silicium with oxygen is known as silica or silicic acid.

Recent investigations have proved, beyond a doubt, that silicium is a metal; for convenience, however, we have preferred to consider it, as formerly, among the non-metallic elements.

Q. Of what is the COMMON QUARTZ rock composed?

A. Almost entirely of *silica.* A pure, transparent quartz crystal is pure silica.

Q. Will you mention some of the OTHER FORMS in which silica is commonly met with in nature?

A. The *common flint*, the *jasper*, the *amethyst*, *opal*, *cornelian*, *chalcedony*, and the *agate* are all varieties of silica. Their brilliant colours are owing to the small quantities of metallic oxides which they contain.

Q. What is the GLASSY COATING which we see outside straw, cane, and the stems of rattan?

A. Pure *silica*, absorbed by the plants from the soil, and settled on the outside of their stalks or stems.

Q. What GOOD PURPOSE does this deposit of silica on the outside of straw, cane, rattan, &c., serve?

A. *Silica* is to these plants what *bones* are to men and animals. It is the substance to which the stalk owes its firmness and stiffness. If the silica be wanting to the stalk, it will bend over.

Q. Of what is COMMON SAND composed?

A. Mainly of *silica*. It is rendered brown or yellow by the presence of oxide of iron (rust).

Q. What is GLASS?

A. Glass is a compound substance, artificially produced by the *combination of silica with the alkalies*. These substances being melted together at a high temperature, unite, lose their solidity, and are melted into a uniform mass, which, on cooling, has the properties of hardness, transparency, and brittleness.

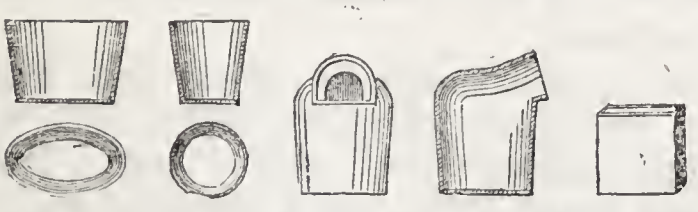
Q. What are the MATERIALS which generally enter into the composition of glass?

A. First and most important is *silica*, which is used in the form of *sand*, *powdered flints*, or *quartz*. An alkaline substance, either potash or soda, is the second substance in glass. Lime is often added to hasten the melting of the mass, and a metallic oxide, generally oxide of lead (red lead).

Q. Why is OXIDE of LEAD generally used in the manufacture of glass?

A. Oxide of lead has the effect of *increasing the density and brilliancy* of glass, and of rendering it more soft and manageable in the manufacture, when in a semi-fluid state.

Fig. 144.



MELTING POTS USED IN THE MANUFACTURE OF GLASS.

Q. Cannot silica be MELTED by ITSELF to form glass?

A. Silica is one of the most *difficult substances to melt known*, and resists the action of the most intense heat. When mixed with an alkali, and submitted to heat, the two unite, the silica playing the

part of an acid; the result is a substance which will readily take the liquid form, and become transparent.

The fusibility or melting of glass depends upon the amount of alkali mixed with the silica; the larger the quantity the greater the fusibility.

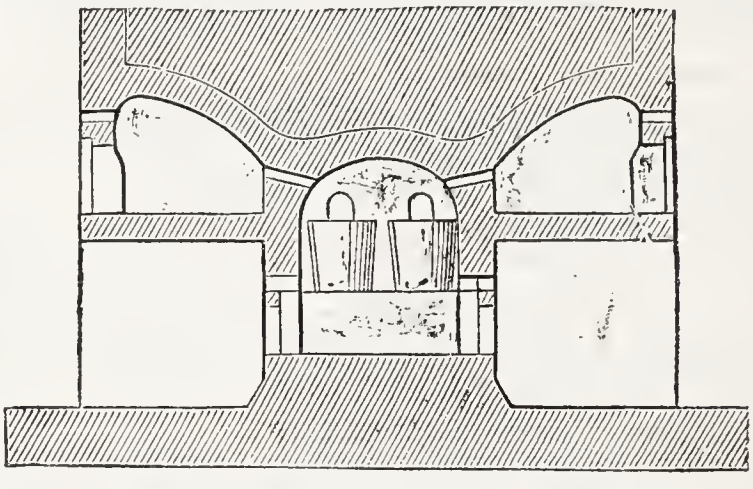
Q. What is the PROCESS of making glass termed?

A. *Vitrification*, and a half-fused, earthy substance is said to be vitrified.

Q. Upon what does the PURITY and quality of glass DEPEND?

A. The quality of glass depends on the *proportion in which the silliceous matter* and the *alkali* are combined, on the temperature to which they are exposed, and on the skill with which they are previously mixed and with which the entire process is conducted.

Fig. 145.



OVEN EMPLOYED IN GLASS BAKING.

Q. Into what THREE VARIETIES is glass divided?

A. Into *crown glass*, *plate glass*, and *flint glass*, the varieties depending on the quantity and quality of the alkali, and the mode of manufacture.

Q. What is CROWN GLASS?

A. The name of crown glass is given to the best kind of *window glass*, that which is *hardest* and most *free from colour*. It is made almost entirely of sand and alkali, with a little lime; but without lead or other metallic oxide. This variety of glass includes what is known as "Bohemian glass." This glass requires a greater heat to melt its ingredients than any of the other varieties.

Q. What is "FLINT GLASS?"

A. Flint glass, so called from its having been originally made of *flints ground to powder, or pulverised*, differs from window glass in containing a large quantity of red oxide of lead. It fuses at a lower temperature than crown glass, has a beautiful transparency, and a comparative softness, which enables it to be cut and polished with ease.

Q. From what DESCRIPTION of GLASS are tumblers, ornamental vessels, and lenses for optical instruments manufactured?

A. From *flint glass*.

Q. How is PLATE GLASS made?

A. It is cast on a *flat metal table*, and after careful annealing, it is *ground and polished* by machinery.

Q. For WHAT PURPOSES is plate glass used?

A. For *mirrors and large window panes.*

Q. How are MIRRORS made?

A. They are made of *plate glass*, covered with an alloy of mercury and tin.

The alloy is formed of 36 parts mercury, 70 tin.

Q. Of what is the common green BOTTLE GLASS manufactured?

A. Of the *cheapest* and *most ordinary materials;* sand, with lime, and sometimes clay, mixed often with common wood ashes, or any other cheap alkaline material. The green colour is owing to impurities in the materials, but chiefly to oxide of iron.

Q. How is glass STAINED and COLOURED?

A. This is accomplished by adding to the *usual ingredients of glass*, as already explained, the *oxides or carbonates of certain metals*, which have the quality of imparting to the structure of the glass a quality in virtue of which it absorbs certain constituents of the solar light, and transmits or reflects others.

Q. What METAL is used to impart a beautiful BLUE tint to glass?

A. *Cobalt.*

Q. What METAL gives to glass a RUBY OR ROSE COLOUR?

A. *Gold; manganese* imparts *pink* or *violet* shades.

Cut-glass ornamental articles, which exhibit different colours upon the same specimen, and at different depths in the thickness of the glass, are manufactured in the following manner: the object is first formed in white, transparent, and colourless glass; then being allowed to cool, until it acquires solidity and consistency, it is dipped for a moment in a pot of coloured glass in a state of fusion, and being suddenly withdrawn, it carries away upon it a thin coating of coloured glass, which immediately hardens upon it and becomes incorporated with it. The article is then shaped by the processes of the glass-maker; and, if it be afterwards cut, those parts which are cut will disclose the clear transparent glass, the parts not cut remaining coated with the colour. It is by this process that all the effects which are seen in ornamental articles, which consist partly of coloured and partly of clear glass, are produced. Additional colours may be combined on the article after being coated, as already described, since glass of one colour may be dipped in the same manner in glass of another colour in a state of fusion, so as to take up another coat of a different colour; and by cutting the surface of such objects to different depths, varieties of effects may be produced, in which two or more colours may be combined.

Q. What are ENAMELS?

A. Enamels are compositions of various substances which, when *vitrified* upon the *surface* of opaque bodies, *communicate their colours*, and produce the *effect of painting.* Enamels are executed on the surface of copper and other metals, by a method similar to painting.

Q. How are artificial GEMS, known as PASTE, prepared?

A. The basis of all artificial gems is the *finest kind of flint glass.* To this are added various metallic oxides, which impart colour and the requisite brilliancy.

Q. When was glass FIRST DISCOVERED and MANUFACTURED ?

A. It is *not known* when glass was first discovered. We find it in the *oldest sarcophagi* of the *Egyptian tombs*, and amid the ruins of *ancient Babylon and Nineveh.* Glass windows do not appear to have been used by the Romans at the commencement of the Christian era, although the art of glass-making had then reached a high degree of perfection.

Q. What is BORAX ?

A. Borax is a compound consisting of *a simple substance* called *boron*, united to *oxygen and soda.* Its chemical name is biborate of soda. It is chiefly obtained from the volcanic districts of Italy, and from Central Asia.

Q. What is borax USED FOR in the arts ?

A. Chiefly as a *flux* for *soldering or joining* one metal with another.

Q. What do you understand by a FLUX ?

A. This name has been given to certain substances which *assist fusion or melting*, either by *expediting the process* or by *protecting the substance* melted from alteration.

Q. Why does a blacksmith, in welding together two pieces of iron, often COVER their SURFACES of contact with BORAX ?

A. The borax *prevents the formation of scale or oxide* on the surfaces of the hot iron, or dissolves any that may previously exist there. In this way it hastens the union of the two metals, for metals only adhere to metals when they have clean, polished surfaces.

Q. Is the clean surface of a piece of iron LOST by strongly HEATING it ?

A. It *is;* because a *layer of oxide is formed upon it* by the oxygen of the air; but the bright surface is restored again by the borax, which when it melts dissolves the oxide formed.

Q. Do we use a FLUX in the smelting of ores of DIFFERENT METALS ?

A. *Always;* in the case of the smelting of iron the metal occurs mixed with various siliceous substances, which are very infusible and difficult to separate from the pure iron. By mixing the ore with a flux, as potash, soda, or lime, the silica unites with it, forms an easily fusible glass, and floats on the top of the melted metal.

Q. What is the refuse, called "SLAG," which we see around iron smelting furnaces ?

A. A *glassy compound* of the *silica* of the *ore* united to the *flux used in the melting.*

Q. Can slag be employed for any USEFUL PURPOSE ?

A. Yes; it has recently been turned to good account by being made to acquire a texture *ten times as durable as marble*, and which can be *polished as highly as agate or cornelian.*

Q. For WHAT PURPOSES can it, then, be used ?

A. Owing to its *durability* it can be employed as a *building material*, while its *beauty* adapts it for purposes of *ornament* or *decoration.*

It is but recently that the refuse of the smelting furnaces has been employed at all. The worth of the rubbish was unknown. Now science has discovered the commercial

value of slag; and by refining, casting, pressing, rolling, moulding, and annealing, renders it at once more lasting and more beautiful than marble. In the hands of the manufacturer this slag can be made to take any shape, assume any texture, or wear any colour. The cheapness of the raw material is another recommendation, for *it costs less than nothing*, a heavy expenditure being now entailed by its removal from the furnace premises. In its preparation, also, cheapness is remarkable, it costing just about half the money to make slag blocks as it does to make clay bricks.

CHAPTER LI.

THE METALLIC ELEMENTS.

Q. In what CONDITION are the metals found in nature?

A. Most frequently in the state of *ore;* that is, combined with other substances in such a way that their metallic properties are in a great measure *disguised.* When uncombined, or when combined only with another metal, they are said to be in a native state.

Q. What are the MOST COMMON states of combination in which the metallic ores are found?

A. As *oxides* and *combinations of oxides* with carbonic, sulphuric, hydrochloric, and phosphoric acid; also with sulphur, forming sulphurets.

Q. What metals possess the GREATEST DENSITY, or weight, within a given volume?

A. *Platinum*, *gold*, *mercury*, and *lead*.

Q. What are the LIGHTEST metals?

A. *Potassium* and *sodium*, the metallic bases of potash and soda. These metals are so light that they float upon water.

Q. What metals possess the most MALLEABILITY?

A. *Gold*, *silver*, *copper*, *tin*, *lead*, *iron*, &c.

Q. What is meant by MALLEABILITY?

A. The property which allows a metal to be *beaten into thin leaves* or *plates* by hammering. Gold surpasses all metals in malleability; one grain of it may be extended so as to cover about fifty-two square inches of surface.

Q. What is an ALLOY?

A. A *combination of a metal with one or more other metals.* Thus brass, type-metal, bronze, &c., are alloys.

Q. What is GERMAN SILVER?

A. German silver, or *white copper*, sometimes called *argentan*, is an alloy of *copper*, *zinc*, and *nickel*.

The best is made of 50 parts copper, 25 zinc, and 25 nickel.

Q. What is BRASS?

A. It is an alloy composed of *copper* and *zinc*.

Good brass contains about 2 parts copper to 1 of zinc.

Q. What is BELL-METAL ?

A. An alloy of *copper* and *tin*. The proportions should be 78 of copper to 22 of tin. Large bells contain more copper than small ones.

Q. What is BRONZE ?

A. Bronze is an alloy of *copper* and *tin*, the proportion of tin being less than in bell-metal. Other metals are sometimes added, but they are not essential. The metal of which the so-called *brass* cannon are constructed is *bronze*.

Q. What is PEWTER ?

A. An alloy of *tin* and *lead*.

In the following proportions : 1 part lead, 20 parts tin.

Q. What is BRITANNIA METAL, such as coffee and teapots, &c., are made of ?

A. It is an alloy of *tin with lead*, *copper*, *antimony*, &c., according to its quality.

Q. What is TYPE METAL ?

A. An alloy of *antimony* and *lead*.

Q. What is the so-called "GALVANISED IRON ?"

A. *Iron covered with zinc*. By plunging an iron plate into melted zinc an alloy is formed on the surface, which prevents oxidation or *rust*.

Q. What is an AMALGAM ?

A. An alloy, of which *mercury* or *quicksilver* is a constituent.

Q. What is ASSAYING ?

A. The term assaying is applied to the process of *analysing metallic ores, so as to discover their component parts*. The assaying of the precious metals is usually confined to ascertaining the quantity of gold or silver in any alloy or compound, without regard to the other constituents.

Q. What are the COMPONENT PARTS of the GOLD COINS of the United Kingdom ?

A. They are made of *gold*, *silver*, and *copper*.

To 90 parts of gold, $2\frac{1}{2}$ of silver, and $7\frac{1}{2}$ of copper.

Q. What are the COMPONENT PARTS of the SILVER COINS of the United Kingdom ?

A. *Silver* and *copper*.

To 90 parts silver, 10 of copper.

Q. What TWO METALS possess the greatest degree of HARDNESS ?

A. *Titanium* and *manganese;* they are harder than steel.

Q. What metals have the GREATEST TENACITY, or the power of resisting tension without breaking ?

A. *Iron*, *copper*, *platinum*, *silver*, and *gold*, in the order enumerated.

Q. What metals are the most INFUSIBLE, or difficult to MELT ?

A. *Platinum*, *iridium*, *titanium*, *chromium*, &c.

Q. What metals are ESPECIALLY BRITTLE ?

A. *Antimony*, *arsenic*, *chromium*, *manganese*, *bismuth*.

Q. What is METALLURGY ?

A. The art of *extracting metals from their ores*.

SECTION I.—THE ALKALI METALS.

Q. What are the ALKALI METALS?

A. *Potassium*, *sodium*, and *lithium*.

Q. Why are they called the ALKALI metals?

A. Because united to oxygen they form the *non-volatile* or fixed alkalies.

Q. What is the APPEARANCE of these metals?

A. They are of a *silver-white colour*, soft, and yield like wax to the pressure of the fingers. They cannot be preserved in a pure state exposed to the atmosphere, as they unite immediately with oxygen; they are therefore kept in some liquid, like naphtha, which contains no oxygen.

Q. When we throw a piece of potassium upon water or ice, what TAKES PLACE?

A. The potassium *abstracts the oxygen from the water*, instantly *catches fire*, and *burns* with a *bright flame;* the product left is potash.

Q. What is the GREAT SOURCE from which we derive our supplies of potash?

A. From the *ashes of land plants.* The plants obtain it from the soil, in which it exists, generally combined with silica. Potash is one of the constituents of granite.

Q. How is the CRUDE POTASH of commerce obtained?

A. In countries where wood exists in very great abundance, as in some parts of the United States, Canada, Russia, &c., it is *burned simply for the ashes.* These are collected, placed in vats and heated with water; the water *dissolves the potash*, and is converted into *ley;* this, when *boiled to dryness*, gives the *crude potash*, or rather a compound of potash and carbonic acid—the carbonate of potash of commerce.

Q. Can we not also obtain potash from the ashes of MARINE PLANTS?

A. *No;* the ashes of marine plants contain *soda*, and but little potash.

Q. What is the SOURCE from which we obtain our supplies of soda?

A. From *common salt* for the most part. Some soda is also obtained from the *earth* in a comparatively *pure state*, combined with carbonic acid. Until within about fifty years, however, nearly all the soda of commerce was derived from the ashes of marine plants.

Q. What is BARILLA?

A. The *impure ashes of marine plants.*

Q. How is soda OBTAINED from COMMON SALT?

A. Common salt is a compound of *chlorine and sodium.* By treating salt with sulphuric acid, we form sulphate of soda; this compound, heated in a furnace with lime and charcoal, is decomposed, and

sulphate of lime and carbonate of soda are formed. This mass is then treated with water, the carbonate of soda dissolves, the sulphate of lime being insoluble, and the ley, evaporated down to dryness, gives carbonate of soda.

Q. By what COMMON NAME is this product known in commerce?

A. As *soda-ash.*

Q. Does potash exist MORE ABUNDANTLY in some portions of the tree, or plant, than in others?

A. The greatest quantity of potash is found in the *fruits and their envelopes.* The parts of a tree which yield the greatest quantity of ash are the limbs and branches; they contain more than the inside wood.

Q. Besides potash, WHAT SUBSTANCES make up the bulk of wood ashes?

A. *Silica* forms the principal substance, with small quantities of lime, magnesia, and iron.

Q. What is PEARLASH?

A. The common *carbonate of potash.*

Q. What is SALERATUS?

A. The *bicarbonate of potash*, or a mixture of potash and carbonic acid, containing double the quantity of carbonic acid that ordinary pearlash does.

Q. What is "CREAM OF TARTAR?"

A. It is *formed of potash and tartaric acid.*

Q. What is TARTARIC ACID?

A. It is a *vegetable acid*, which gives in part to sorrel its sour taste, and imparts acidity to the branches of grape-vines, unripe grapes, &c. It also exists in considerable quantities in the juice of ripe grapes.

Q. Why do not ripe grapes taste SOUR, if they CONTAIN this ACID?

A. Because they also *contain sugar*, which *neutralises the acid.* The sour taste of the acid is thus concealed by the sweet taste of the sugar.

Q. How do we obtain "CREAM OF TARTAR?"

A. It is deposited in *wine-casks*, as a gray or reddish crust, from the wine or juice of the grape; this, refined and purified, constitutes "cream of tartar."

Q. Why are bodies containing potash valuable as MANURES?

A. Because potash is *indispensable* for the *nourishment of certain kinds of plants.* Thus, on a soil destitute of potash, neither potatoes, turnips, nor grape-vines will flourish.

Q. How can we ascertain what MINERAL SUBSTANCES are essential to the nourishment of plants?

A. By *burning the plant*, and examining the *ashes.* The substances which are found, though their amount is generally very small, must be regarded as necessary to the life of the plant.

Q. Is a soil DESTITUTE of potash adapted to the GROWTH of OTHER PLANTS?

A. It *is*, unless it be entirely *barren*. Thus, in a soil from which potash has been exhausted, clover and peas will flourish if lime be present, for in these plants lime will take the place which potash fills in potatoes, turnips, &c.

Q. EXPLAIN what is meant by the ROTATION of crops.

A. If turnips are cultivated season after season upon the same field, the *potash* will finally be *exhausted*, and turnips will no longer grow there; the same thing will happen when peas are planted year after year upon the same land, as they will at last exhaust all the soluble lime from the soil. But turnips will flourish in this latter field, because it still contains potassa, and peas in the former field, where lime is still present. This explains the theory of the rotation of crops, which has now been everywhere introduced into agriculture.

Q. How does it benefit a field to LIE FALLOW, or UNCULTIVATED, for a time?

A. Generally when we say that potash or lime has been exhausted from a field by cultivation, we mean that all of these substances, in a soluble state, or in a state adapted as food for plants, are wanting. The field still contains quantities which are *united with silica* in rocks and earth, in an insoluble state. By the action of the *elements*, in time, portions are rendered *soluble*, and the land again acquires its former fertility.

Q. What is the POPULAR MEDICINE known as "GLAUBER SALTS?"

A. *Soda* united to *sulphuric acid*, forming sulphate of soda.

SECTION II.—METALS OF THE ALKALINE EARTHS.

Q. What METALS united with oxygen form the alkaline earths?

A. *Barium*, *strontium*, *calcium*, and *magnesium*.

Q. Why are the OXIDES of these metals called ALKALINE EARTHS?

A. Because in appearance they *resemble earth*, and yet have *alkaline properties*. Thus, lime, the oxide of calcium, neutralises acids, turns vegetable colours, and has a caustic or corroding action on animal and vegetable substances.

Q. Are the metals which exist in baryta, strontia, lime, and magnesia, easily obtained in a PURE STATE?

A. They are united so closely to oxygen, and have such an affinity for it, that it is *almost impossible* to separate them in a pure state. Thus far, only very small quantities of them have been prepared.

Q. What is their APPEARANCE?

A. Barium is a *dark-coloured metal*, somewhat resembling cast-iron; strontium is *similar in appearance to barium;* calcium is a *white metal;* and magnesium is *very brilliant*, resembling silver.

Q. What is CHALK?

A. *Lime* united to *carbonic acid*, forming carbonate of lime.

Q. What is MARBLE?

A. *Carbonate of lime*, having the same composition as chalk.

Q. Of what are the SHELLS of OYSTERS, and other marine animals, composed?

A. Almost entirely of *carbonate of lime.* Pearl is also a carbonate of lime.

Q. Since all these substances have the same composition, how can you ACCOUNT for their very DIVERSE APPEARANCES?

A. Marble has been subjected, in the interior of the earth, to heat and pressure, and the carbonate of lime composing it has *become crystalline;* chalk is wanting in *crystalline arrangement;* and the lime of shells has its appearance in some degree changed by its connection with animal matter.

Q. When you pour an acid upon a piece of limestone, chalk, or marble, why does it EFFERVESCE?

A. Because the *carbonic acid* is liberated from its combination with the lime, and escapes.

Q. What is GYPSUM, or "PLASTER OF PARIS?"

A. A *compound of lime and sulphuric acid*—sulphate of lime.

Q. Can you explain how it is that the "plaster of Paris," used for ornamental figures and designs, HARDENS SO RAPIDLY when moistened with water?

A. The gypsum used for figures and designs is known as *calcined plaster.* The rock is first pulverised, and then strongly heated, until it loses one-fifth of its weight by the expulsion of moisture from its composition. When mixed with water, the anhydrous burnt gypsum again chemically combines with it, and passes into a solid state.

Q. What is ALABASTER?

A. A very fine compact *variety of gypsum.*

Q. Why is gypsum valuable as a MANURE?

A. Because it affords a supply of *lime to the soil*, and it absorbs and fixes the ammonia of rain water and of decaying animal substances.

Q. Why is it difficult to heat water in a vessel COATED upon the INSIDE with "PLASTER OF PARIS?"

A. Because the plaster is so *bad a conductor* that the heat passes with great difficulty from the fire to the water.

Q. What PRACTICAL APPLICATION has been made of the non-conducting properties of plaster, as regards the transmission of heat?

A. By availing ourselves of the *non-conducting properties of plaster of Paris* we render metal safes fire-proof. The so-called fire-proof safes are constructed of double or treble walls of iron, with spaces between filled with plaster of Paris. This lining prevents the heat from passing from the exterior of the safe to the books and papers within.

Q. Why is gypsum called "PLASTER OF PARIS?"

A. Because immense *beds* or *deposits of this substance* are found in the *vicinity of Paris*, in which city it was first extensively used as a plaster or cement.

Q. Why is quicklime called CAUSTIC LIME?

A. Because, like potash and soda, it exerts a *corrosive* and *destructive action* upon most animal and vegetable substances.

Q. What is ordinary WHITEWASH?

A. A mixture of *slaked lime with water.*

Q. What is SLAKED lime?

A. When quicklime is exposed to the air, it *rapidly attracts water*, and *crumbles to powder.* Lime which has thus united with water is termed *slaked lime*, or, in chemical language, *hydrate of lime.*

Slaked lime, if further exposed to the air, absorbs carbonic acid, and is converted into carbonate of lime. Slaked lime, if mixed with water, so as to form a paste, is mortar; if more water is added, it becomes milk of lime, or whitewash; and when mixed with six hundred times its quantity of water, a clear solution is obtained—lime-water.

Q. Why should BEDROOMS, COTTAGES, HOSPITALS, and STABLES be occasionally WHITEWASHED?

A. Because the lime is very *caustic*, and *removes all organic matters* adhering to the walls.

Q. Why should we avoid MIXING caustic or slaked lime with MANURE that is already in a state of PUTREFACTION?

A. Because the manure in this state contains *ammonia compounds*, which would be *decomposed* by the lime, and the ammonia set free. The ammonia *escaping* into the air, *deprives* the *manure* of much of its *efficacy.*

Q. What is the SUBSTANCE used for producing the beautiful crimson flame of fireworks?

A. *Nitrate of strontia;* a compound of strontia, oxygen, and nitric acid.

Q. What is it that gives to SOAPSTONE its SLIPPERY or GREASY feeling?

A. The presence of *magnesia* in its composition.

Q. What are EPSOM SALTS?

A. A compound of *magnesia* and *sulphuric acid*—sulphate of magnesia.

Q. What is MEERSCHAUM, of which pipes are made?

A. A compound of *magnesia* and *silica.* Before being made into pipes it is boiled in a mixture of wax and oil.

SECTION III.—ALUMINUM.

Q. What is ALUMINUM?

A. A beautiful *bright metal*, very much resembling *silver*, but *lighter.* It possesses the remarkable property of not becoming tarnished or oxidised by exposure to the atmosphere. Hitherto it has

been obtained only in very small quantities: its value is about double that of silver. Common clay contains about one-fourth part by weight of this metal.

Q. What is common CLAY?

A. A compound formed by the union of *aluminum* and *oxygen* united with *silica*. The chemical name of clay is *silicate of alumina*.

Q. In what substances do we find PURE ALUMINA in nature?

A. The most costly red precious stone, the *ruby*, and the most costly blue precious stone, the *sapphire*, are crystallised alumina. *Emery*, that is used for polishing, is alumina, and when pure is the gem *corundum*.

Q. What is ALUM?

A. A compound of *sulphate of alumina* and *potash*, with twenty-four parts of water.

Q. What is "FULLERS' EARTH?"

A. A *soft variety of clay* used in *woollen manufactories* for removing the grease and oil applied to wool in spinning.

Q. How is clay enabled to extract GREASE from WOOL and other substances?

A. Clay possesses the property of *absorbing oily* and *colouring matters when in solution*, and retaining them within its composition.

Q. What is the most EFFECTUAL WAY of REMOVING GREASE or oil spots from carpets, woollen cloths, paper, &c.?

A. Cover the oiled surfaces with a *fine variety of clay*, and allow it to remain in contact with them for several days. In this way a great proportion of the greasy matter will be absorbed and removed by the alumina of the clay.

Q. Why is a soil abounding in clay termed a COLD SOIL?

A. Because clay has a very great capacity for *retaining water*; this, slowly evaporating, causes the earth to remain for a long time cold and wet. A soil rich in clay is generally unproductive, since being compact and heavy, it will not allow the roots of plants sufficient room to spread; it likewise prevents the free circulation of air and water among the particles of the soil.

Q. Why does it benefit a clay soil to BURN OVER THE SURFACE THOROUGHLY?

A. All clay and loam contain, combined in their composition, various proportions of potash, lime, soda, and silica. By burning the clay, these are to a considerable extent *decomposed* and *rendered soluble*, thus modifying and benefiting the character of the soil.

Q. Does ALUMINA enter into the COMPOSITION of PLANTS, and consequently into the structure of animals?

A. Although alumina exists in the soil in great quantities, it is *not known* as yet *to enter into the composition of any plant or animal.* All the other constituents of the soil appear to be taken up by plants in a greater or less degree.

Q. What are the PROPERTIES which render clay so eminently suitable for the manufacture of pottery, earthenware, porcelain, &c. ?

A. Clay, when mixed with water, is capable of being moulded into various forms, and of acquiring, when exposed to the heat of a furnace, an almost stony hardness.

Q. What is PORCELAIN ?

A. All kinds of *china-ware*, such as are used for dishes, cups, &c., are denominated *porcelain ;* some kinds are much finer and more beautiful than others.

Q. Of what is porcelain COMPOSED ?

A. The chief materials used in its manufacture are a certain clay derived from *decomposed feldspar*, *calcined flints* finely ground, together with a portion of feldspar reduced to powder.

"*Feldspar*," a species of mineral. "*Calcined*," heated immensely hot so as to crumble.

Q. How are these materials MIXED TOGETHER ?

A. They are put into a *kind of mill*, which is a large cylindrical vessel or tub, into which a *small stream of water* is constantly suffered to trickle ; the mass is now ground or mixed into a kind of dough. This dough is kneaded or worked with the hands until the mass is quite smooth and of a uniform colour. It is now ready for moulding.

Fig. 146.

MOULDING PORCELAIN.

Q. What is MOULDING ?

A. Forming the dough or paste into the *shape required*, such as bowls, plates, cups, &c.

Q. How are these articles MOULDED ?

A. The operation is performed on a machine called a *potter's wheel* or *lathe.* A small piece of the clay or dough is placed upon this lathe, and owing to the rapid rotary motion of the machine, the workman is able to shape a vessel by keeping his hands constantly wet; he moulds it to a proper size by means of tools and gauges. It is now suffered to dry partially; it is then placed upon another lathe, when it is shaped more evenly and accurately, and nicely smoothed and burnished with a smooth steel surface. The vessels are then put in a kiln and baked.

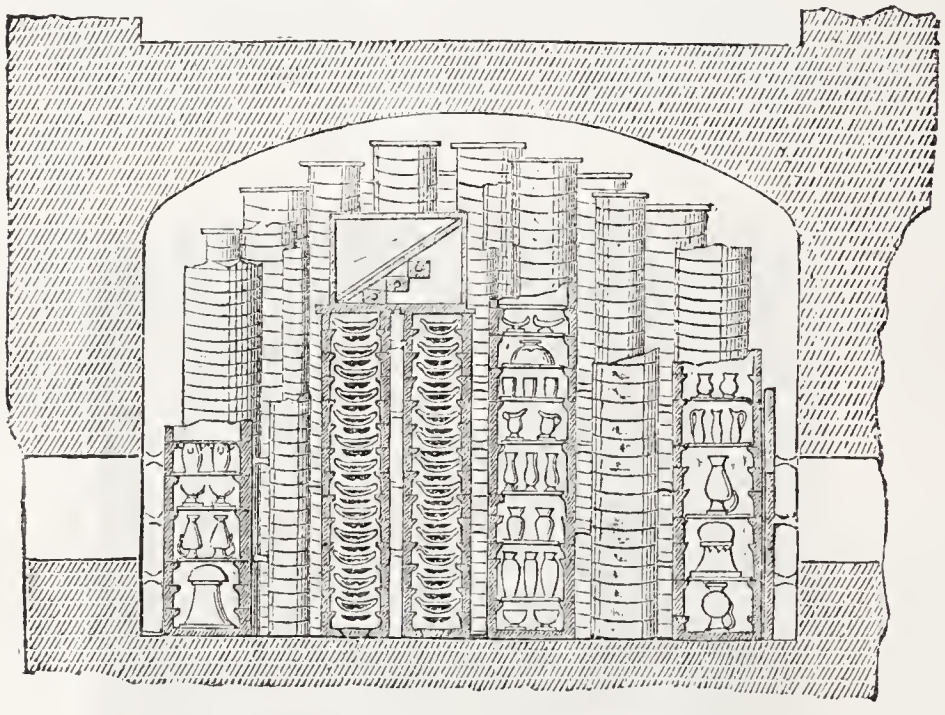
Q. How LONG is porcelain usually baked ?

A. It requires *forty hours* or *more.*

Q. Though porcelain acquires, by baking, great hardness and solidity, yet it still remains so porous as to imbibe water, and also allows it to filter through its substance : how is this REMEDIED ?

A. By covering the ware with a *vitreous coating*, which is called a *glaze.*

Fig. 147.



BAKING PORCELAIN.

This glazing is effected as follows :—

A mixture of oxide of lead and ground flints is generally used for glazing. These materials are first ground to an extremely fine powder, and mixed with water, to form a thin liquid. The ware is dipped into this fluid and withdrawn. The moisture is soon absorbed by the clay, leaving the glazing particles upon the surface. These are afterwards melted by the heat of the kiln, and constitute a uniform and durable vitreous coating.

Q. How is STONEWARE, such as is used for jugs, jars, &c., made ?

A. This is a very coarse kind of porcelain, made from *clay containing oxide of iron* and a *little lime.*

Q. How is stoneware GLAZED ?

A. By throwing *common salt* into the heated furnace : this is

volatilised and unites with the silica of the clay, of which the ware is composed. The mixture formed fuses over the surface of the ware, and gives a thin but excellent glaze.

Q. What is EARTHENWARE?

A. This is composed of a *species of clay mixed with silica.* It is moulded in the same manner as porcelain, dried, and baked in a kiln; after that it is glazed with a mixture, which contains the oxides of lead and tin, after which it is reheated.

Q. How is porcelain GILDED?

A. The gold is reduced to a *state of oxide*, and *ground up* with *oil of turpentine* and some substance having the property of a flux. It is then printed upon the ware with a brush and exposed to heat. The oxygen of the gold is drawn off, and the metal, by the action of the flux, cemented to the porcelain.

Q. What is it that renders the finer varieties of porcelain so COSTLY and EXPENSIVE?

A. Not the value or quality of the materials which enter into their composition, but the *labour bestowed upon their preparation* and *ornamental decoration.* In richly-painted porcelain the articles enter the kiln four or five times.

Q. What is the COMPOSITION of FIRE-BRICKS, used for the lining of furnaces?

A. They are made of a *variety of clay*, which contains but a small proportion of the alkalies or alkaline earths or oxide of iron. These substances tend to make clay fusible, and their absence enables the clay to resist the action of heat.

Q. Why does the stem of a new tobacco-pipe ADHERE to the LIPS with considerable force when first used?

A. Tobacco pipes are composed of *baked clay*, which has a great *attraction for water*, so that when a new pipe is put into the mouth, it *absorbs the moisture from the lips*, and adheres with force to the skin.

Q. What is the material called "PARIAN," of which statuettes are manufactured?

A. A very carefully prepared *variety of porcelain.* It is called "Parian," from its resemblance to the celebrated Parian marble of Greece.

SECTION IV.—THE HEAVY METALS.

Q. In what respect does IRON DIFFER from all other metals?

A. It is the only metal which is *not injurious to the health*, the only metal that *always forms an element of the body*, especially of the blood, and the only metal which is *found everywhere upon the earth*, in almost all stones, rocks, soils, and in almost every plant.

Q. Is iron found PURE on the surface of the earth?

A. The occurrence of native iron on the surface of the earth, except in meteoric masses, is *exceedingly rare.*

Q. What is OCHRE?

A. An *oxide of iron;* the colour is generally red or yellow. Ochres are much used as a cheap material for paints.

Q. What is the cause of the BEAUTIFUL FILM of colour which often invests the surface of stagnant waters?

A. It is due to a thin *film of oxide of iron*, which has become separated from the water in which it was formerly held in solution. A very thin film of oxide of iron gives a yellow reflection; a thicker film, a red or brown, and a still thicker one, a violet and blue reflection.

Q. Why are the stones in the beds of brooks and rivers generally of a BROWN or YELLOW colour externally?

A. Because an *oxide of iron* has been *deposited upon them* from the water.

Q. What is CAST IRON?

A. Cast iron is the metal obtained by *smelting the ore with carbon.* It is by no means pure iron, as it contains carbon, silica, some aluminum, and generally sulphur and phosphorus. It is fusible at a glowing white heat, is brittle, and can neither be forged nor welded.

Q. What is WROUGHT, MALLEABLE, OR BAR IRON?

A. Cast iron, *deprived of its carbon* and other impurities, is converted into malleable iron. It is not fusible at a white heat, and may be forged and welded.

The process of "puddling," or converting cast iron into wrought iron, is as follows:—The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flames. After a time the mass heaves, emits a blue flame, gradually grows tough, and becomes less fusible, and at length pulverulent; the fire is then urged, so that the particles again agglutinate at a welding heat, and are gradually wrought up into masses. In that state of intense heat the masses are passed successively through rollers, and converted into malleable bars. They are then cut into pieces, placed in parcels in a very hot reverberatory furnace, and again hammered or rolled into bars. In this way the excess of carbon existing in the cast iron, and most of the other impurities, is expelled from the metal, and the iron rendered nearly pure.

Q. Why does a drop of nitric acid, let fall upon steel, occasion a BLACK spot?

A. Because the iron is *dissolved*, and the *carbon* in combination with it exposed to view.

Q. Upon WHAT PECULIARITY does the capacity of wrought iron for welding depend?

A. At a certain degree of heat, less than that of fusion, *iron* becomes soft like wax or glass, so that two glowing pieces may be cemented or welded into one.

Q. Is this property of WELDING possessed by any of the OTHER metals?

A. *None* of the other metals, except *platinum*, can be welded. All the others become fluid instantaneously, as is the case with ice, without undergoing previous softening.

Q. What is understood by the "TEMPERING of steel?"

A. The process of tempering gives to steel instruments a quality intermediate between hardness and ductility, which insures to them the proper degree of strength under the uses to which they are exposed.

Q. In what MANNER is this effected ?

A. After the steel has been sufficiently heated, and hardened by cooling rapidly, it is *partially softened*, or let down to the proper temper, by heating it again to a less degree, or to a particular temperature suited to the hardness required, after which it is again cooled by plunging it into cold water.

Q. When steel is heated it assumes various colours, which succeed each other as the temperature increases ; first yellow, then orange, crimson, violet, blue, and dark gray : what OCCASIONS these colourations ?

A. The cause of these colours is *the same* as that which produces *iridescent appearances* on the surface of standing waters containing iron.

A film of oxide of iron forms upon the steel through the agency of the heat ; at first the film is thin, and has a yellow appearance, but gradually it becomes thicker and also darker, as the heat increases. The final result, the dark gray coating, is iron scales.

Q. Do these different colourations which steel assumes, on being heated, CORRESPOND with a DEFINITE DEGREE of hardness and elasticity ?

A. They *do;* when the steel is covered with a *yellow film* it is *hard* and *brittle;* when it presents a bright *blue* appearance it is in its *softest* and *most elastic* condition. This bright-blue colour is especially to be noticed on swords and watch-springs.

Q. What is COPPERAS, or GREEN VITRIOL ?

A. A *compound of iron and sulphuric acid*—sulphate of iron. It is principally manufactured from the sulphuret of iron—iron pyrites —by oxidation. This is effected by exposing the sulphuret of iron to moisture and the action of the atmosphere.

Q. For WHAT PURPOSE is copperas, or green vitriol, chiefly used ?

A. For *dyeing blacks* or *browns* in *calico printing*, and for the preparation of *inks.*

Q. As a solution of copperas has but little colour, how can it be used for DYEING BLACK ?

A. When *copperas* in solution is brought in contact with *gallic* or *tannic acid*, a dense *black fluid* or precipitate is formed, the acid uniting with the oxide of iron to form gallate or tannate of iron. If you dip a linen rag in a solution of gallic acid, and then into a solution of copperas, a black colour is formed in the fibre itself, and adheres so firmly that it cannot be washed out.

This is the general method of dyeing cloths, leather, and hair. Hats are also coloured black in a similar manner.

Q. What is GALLIC acid ?

A. Gallic acid is a *vegetable acid* extracted from *gall-nuts.* The gall-nut is an excrescence produced upon an Asiatic species of oak, by the puncture of an insect.

Q. What is TANNIC acid ?

A. Tannic acid (tannin) is the name given to that substance which exists in the *bark* of *some trees*, which imparts to them the well-known astringent taste. It especially abounds in the *bark* of the *oak*, *hemlock*, and *birch.*

Q. How is the permanent BLACK colour given to leather of which boots and shoes are made?

A. The leather, containing *tannic acid*, is washed with a *solution of iron;* the tannic acid, uniting with the iron, gives to the leather its permanent black colour.

Q. How is common WRITING INK prepared?

A. All the common black inks are prepared from *gallic* and *tannic acids* and a *salt of iron*, generally *copperas*. The acids uniting with the oxide of iron produce a deep black precipitate; to prevent this from settling, and for thickening the fluid, a mucilage of gum-arabic is added.

Q. Why does the pale colour of fresh ink grow DARKER when exposed to the air upon paper?

A. The iron contained in the ink assumes an *additional quantity of oxygen*, and with it a darker colour.

Q. How can MOULDINESS in ink be COUNTERACTED?

A. By the addition of a small quantity of the *oil of cloves*, *creosote*, or *corrosive sublimate;* the latter in small amount is probably more efficient than all others, but it should be remembered that it is a deadly poison.

Q. How may the STAINS of ink prepared from tannic or gallic acid and iron be REMOVED from paper, cloth, &c.?

A. By a *solution of chlorine* (bleaching powder), or by *phosphoric* or *oxalic acids.*

Q. How can FADED writings be RESTORED?

A. By washing the paper with a *decoction of galls.*

Q. What is the brilliant pigment called "PRUSSIAN BLUE?"

A. A compound of *iron* and *cyanogen.*

Q. How is BLUE INK prepared?

A. Blue ink is generally made by dissolving *sulphate of indigo*, or *basic Prussian blue*, in water, and *thickening the solution with a little gum.*

Common Prussian blue is rendered soluble in water by the addition of muriatic or oxalic acids. If the soluble blue be added to common black ink (from galls), the result is a black ink which cannot be removed from paper without destroying it.

Q. What is WHITE VITRIOL?

A. Sulphate of zinc.

Q. How is the oxide of zinc, or the "zinc white," used for paints PREPARED?

A. The *ore of zinc* mixed with *coal* is smelted in a furnace at a high temperature. The metallic zinc rises as a *vapour;* on coming in contact with the air this vapour *unites with oxygen*, and bursts into a flame; while the products of combustion, the *oxide of zinc*, fall in clouds as a beautiful white impalpable powder or dust.

Q. What is BLOCK TIN?

A. Tin *purified by heat* and run into moulds, which form blocks of great size.

Q. What is SHEET TIN, such as is used in the manufacture of pans and other utensils ?

A. It is sheet iron dipped into melted tin, a portion of which adheres to the surface.

Q. From WHAT COUNTRIES do we obtain our supplies of tin ?

A. From the mines of *Cornwall ; Malacca*, in the East Indies ; and a little from *South America.*

Q. Why are TIN pipes PREFERABLE for the conveyance of water for household purposes to LEAD pipes ?

A. Because the *compounds* which carbonic acid, and other substances contained in water, form with the tin are not so *injurious* to health, if taken into the system with the water, as the compounds of lead are.

Q. What is the COMPARATIVE STRENGTH of lead and tin pipe of equal dimensions for the conveyance of water ?

A. The strength of tin pipe to resist the internal pressure of water is at least *threefold greater* than that of lead.

Q. What METAL stands next to iron in ABUNDANCE and CHEAPNESS ?

A. Lead ; it is rarely found pure in nature, but in combination with sulphur it occurs in great quantities. The ore of lead and sulphur is called "*galena.*"

Q. Is lead a POISON ?

A. Lead and nearly all its compounds are *dangerous* and *secret poisons.* When received into the system it frequently remains dormant for years, and then suddenly manifests itself in various forms of disease.

Q. What is the disease called "PAINTER'S COLIC ?"

A. A disease to which painters and others working in lead *are liable*, in consequence of receiving into their system, imperceptibly, portions of lead.

Q. Is it DANGEROUS to sleep in, or breathe the air of, a room newly painted with paints containing lead ?

A. It is *highly dangerous*, since the air is filled with a vapour of the lead compound used as paint.

Q. Why are some WATERS, when conveyed through LEAD pipe, POISONOUS ?

A. Waters which are *very pure* and contain *much oxygen* dissolved in them; waters which contain *nitric acid* compounds, such as those flowing from the vicinity of barn-yards, manure heaps, and those which contain *common salt* or *organic matter*, as water flowing from swamps and fields; waters containing soluble *carbonates*—all dissolve lead from the pipes through which they may be made to pass. Constant use of such waters, in the process of time, will introduce sufficient lead into the system to produce disease, which is often attributed to other causes.

Q. WHAT waters may be safely conveyed through lead pipes ?

A. Those which contain *sulphate of lime.* The sulphuric acid acts upon the lead, and forms a compound of *sulphate of lead* on the interior of the pipe, which the water cannot dissolve.

Q. What is LITHARGE, used extensively in the manufacture of glass, &c. ?

A. A compound of *lead* with *oxygen*—the protoxide of lead.

Q. What is the so-called WHITE LEAD, used for painting ?

A. A compound of *oxide of lead* and *carbonic acid.*

Q. What is SUGAR of lead ?

A. A compound of *oxide of lead* and *acetic acid*—acetate of lead.

Q. What is ACETIC acid ?

A. The acid existing in *vinegar.*

Q. How are SHOT manufactured from lead ?

A. The lead is melted at the top of *high towers* built for the purpose, and poured into a vessel which is perforated with *numerous small holes* in the bottom. The lead, after running through these perforations, immediately separates into *drops*, which *cool* in falling through the height of the tower, and are received in a *reservoir of water* at the bottom to break the force of the fall.

Q. How are shot so manufactured PROVED, and the different sizes SEPARATED ?

A. By *rolling them down an inclined board.* Those which are irregular in shape roll *off* at the sides or stop, while the spherical ones continue to the end.

Q. What is the beautiful green pigment called VERDIGRIS composed of ?

A. Of *copper* united to *oxygen* and *acetic acid.* It is prepared on a large scale either directly from copper and vinegar, or indirectly by packing sheets of copper with the refuse of pressed grapes, the juice of which gradually passes into vinegar.

Q. Is verdigris a POISON ?

A. Verdigris, in common with all the compounds of copper, is *very poisonous.* The most efficacious antidotes for poisoning with copper are white of eggs and milk.

Q. When copper is exposed to the air and moisture, it gradually becomes covered with a greenish coating : to WHAT is this appearance DUE ?

A. To the formation of a *carbonate of copper;* carbonic acid being absorbed from the atmosphere and from water by the metal.

Q. In what respect does MERCURY differ from all other metals ?

A. It is the only metal which is *fluid* at common temperatures.

For this reason, and also on account of its silver-white brilliancy, it has been called *hydrargyrum* (water silver, or liquid silver). This name is still retained in medicine. Subsequently, on account of its mobility, it was dedicated to Mercury, the most active of the heathen gods, and received his name.

Q. Does mercury ever become SOLID at natural temperatures ?

A. In *Siberia*, and *within the polar circles*, mercury often solidifies through the intensity of the natural cold.

Q. If you make a stroke across a brass plate with a stick or brush dipped in solution of mercury, and afterwards bend the plate at this place, it will break as though it had been cut : WHY is this EFFECT PRODUCED ?

A. Because the *mercury* of the solution at once *penetrates* and *combines with the brass*, and renders it *brittle.*

Q. What is CALOMEL ?

A. It is a compound of *two parts of mercury* united to one of *chlorine*, forming the subchloride of mercury. The preparation commonly known in medicine as "blue pill" is a preparation of calomel.

Q. What is CORROSIVE SUBLIMATE ?

A. A compound of *mercury* and *chlorine* united in equal proportions, forming the perchloride of mercury.

Q. Are both these compounds, calomel and corrosive sublimate, POISONS ?

A. They *are;* corrosive sublimate, especially, is a most *deadly poison.* In cases of poisoning by it, the most effectual antidote is white of eggs.

Q. What is the process of PRESERVING WOOD from decay, commonly termed "KYANISING ?"

A. It consists in *saturating* the fibres of the wood with a *solution of corrosive sublimate.*

Poisonous substances, and corrosive sublimate especially, have the property of protecting animal and vegetable substances from decay. The skins of stuffed birds and animals, and the plants of a herbarium, may be protected from insects and decay by washing them with a solution of corrosive sublimate. It should not, however, be forgotten that these substances, by such treatment, become themselves poisonous.

Q. What is the beautiful red pigment called "VERMILION ?"

A. A compound of *mercury* and *sulphur*—sulphuret of mercury.

Q. In what STATE is mercury found in nature ?

A. Generally as a *compound of mercury* and *sulphur*—forming a beautiful red mineral called *cinnabar.* In some places it is also found pure.

Q. From WHAT COUNTRIES do we derive our supplies of mercury ?

A. From the mines of *Idria* in Austria, *Almaden* in Spain, *California*, and *South America.*

Q. Why are silver, gold, and platinum called NOBLE metals ?

A. Because, when exposed to the action of air or moisture, they do *not rust;* when exposed to heat, they do not *oxidise* or *volatilise;* and they are of comparatively rare occurrence in nature.

Q. Why are silver and gold, when employed as money, or used in the arts, generally ALLOYED, or mixed with other metals ?

A. Silver and gold in their pure state are *very soft*, and would in this state quickly wear out by using. By alloying them to a small extent with copper these metals are rendered harder without losing their lustre.

Q. When is silver called "FINE ?"

A. In purchasing silver plate, &c., the question is always asked, What is the proportion of pure silver in eight ounces? If it amounts to seven and a half ounces, the silver is said to be *seven and a half ounces fine;* if six, four, or two ounces of silver are contained in it, it is understood to be six, or four, or two ounces fine.

Q. How fine is the silver commonly used for PLATE or COINS?

A. *Six ounces fine;* that is, eight ounces of the plate or coin contain three-fourths silver and one-fourth copper.

Q. How are ornaments of iron, such as carriage and harness trimmings, PLATED with silver?

A. The iron is first covered with a *coating of tin*, and upon this surface a *thin plate of silver* is applied. The whole is then submitted to a *heat* sufficient to *melt* the tin and form an alloy, the fusion being aided by the employment of a flux.

Q. What is the VALUE of SILVER?

A. About *five shillings per ounce.*

Q. What is the VALUE of GOLD?

A. About *four guineas per ounce.*

Q. How do we designate the PURITY of gold?

A. The quantity of pure gold contained in a mass is expressed by the word *carat*, the standard number not being eight as in silver, but twenty-four. Perfectly pure gold is said to be twenty-four carats fine. If gold is said to be eighteen carats fine, it is understood that the mass consists of *three-fourths* (eighteen parts) *gold*, and *one-fourth* (six parts) of *alloy.*

Q. Is there any SOLVENT for gold?

A. None of the acids alone can dissolve gold; *chlorine* is the only means of rendering it soluble. Commonly the chlorine is obtained for this purpose by mixing muriatic (hydrochloric) acid with nitric acid; in this mixture, known as *aqua regia*, the gold dissolves completely by sufficient heating, producing a brownish-yellow liquid (solution of gold).

Q. What is BULLION?

A. *Gold and silver* reduced from the ore, but *not yet manufactured.* At the mint, it means all gold and silver suitable for *coining* purposes.

Q. How is GOLD-LEAF manufactured?

A. Gold forged into plates is first rolled into a *thin ribbon* by means of steel rollers. This ribbon is divided into small squares, which are placed between leaves or sheets of gold-beater's skin (a thin membranous substance obtained from the intestines of animals), and the whole beaten with a heavy hammer. As the gold expands, it is divided and subdivided until the required thinness of leaf is obtained.

Q. What is PLATINUM?

A. Platinum is the *heaviest known metal*, possessing a *lustre inferior to silver*, and of a *whitish colour.* It is found only in the metallic state, generally in small grains, often mixed with gold.

Q. What are the PROPERTIES of platinum?

A. It is *not affected by air* or moisture, or oxidised by heating. It is tenacious, ductile, and can be welded like iron. It is infusible by the strongest furnace heat. Its value is intermediate between silver and gold, and in Russia it has been coined into money.

Q. Is there any SOLVENT for platinum?

A. Platinum, like gold, only dissolves by *heating* it in *aqua regia*.

Q. What are the CHARACTERISTICS of the metals PALLADIUM, IRIDIUM, RHODIUM, and OSMIUM?

A. They all *resemble platinum*, and are always found in very small quantities associated with it. Iridium, from its great hardness, is used for pointing the tips of gold pens.

Q. What is ANTIMONY?

A. A *brittle metal*, of a *whitish colour*, used in the composition of type-metal.

All the soluble preparations of antimony are poisons, and consequently the stomach violently exerts itself to remove from it all such compounds introduced into it. This is effected by vomiting, and, for the reason of its emetic properties, antimony has become a very important medicine.

Q. What is the COMPOSITION of the well-known "TARTAR EMETIC?"

A. It is a *compound of cream of tartar* and *tartaric acid*, united to oxide of antimony. Dissolved in wine, it forms "wine of antimony."

Q. What is ARSENIC?

A. Metallic arsenic is an *exceedingly brittle metal*, of a *steel gray colour*. It vaporises, when heated, with a strong smell of garlic—a property not possessed by any other metal.

The substance used as poison, and sometimes known as ratsbane, is arsenious acid, a compound of arsenic and oxygen. Arsenious acid has the form and appearance of a fine white powder.

Q. What is the BEST REMEDY in cases of POISONING with arsenic?

A. A certain remedy is the *hydrated peroxide of iron* (iron rust). Before this remedy and the aid of a physician can be procured, it is well in cases of poisoning by arsenic, and in cases of poisoning generally by mineral substances, to administer milk, white of eggs, sugar, or soap-suds.

Q. Can we detect with certainty arsenic in the body, when it has been administered in poisoning?

A. There is no poison *so liable* and *certain* to be found as *arsenic;* and in almost every case of poisoning with mineral substances, science is enabled to detect the substance, even when life has been extinct for years, and the body nearly decomposed.

Q. How does the MANNER in which the metallic elements are DISTRIBUTED over the surface of the earth illustrate the wisdom and beneficence of the Creator?

A. All those metals which, either *pure* or compounded, are *prejudicial* or *poisonous* to the animal system, are comparatively *rare*, or exist in such forms that they are *not soluble in water*.

If the oxides of copper or lead were as widely distributed as iron, the result to all animated beings would be most disastrous. Had carbonate of baryta been as abundant as carbonate of lime, all forms of life would have failed before its influence.

ORGANIC CHEMISTRY.

CHAPTER LII.

CONSTITUTION AND FORMATION OF ORGANISED BODIES.

Q. What is ORGANIC CHEMISTRY?

A. Organic chemistry is that science which *treats of the substances which form the structure of organised beings*, and of their products, whether animal or vegetable.

Q. What are the ELEMENTS which compose ORGANIC SUBSTANCES generally?

A. *Carbon*, *hydrogen*, *oxygen*, and *nitrogen*, a little phosphorus and sulphur, and sometimes a small proportion of two or three alkaline and earthy compounds, are the sole materials which have been employed in the construction of all the countless multitudes of orders of living objects which people the earth and clothe it with beauty.

Q. What is the FORCE which governs and controls the elements existing in living organic structures?

A. *Vital force;* we recognise it as life only by its actions; of the nature of the force we are ignorant.

Q. Under what FORM does animal or vegetable life first manifest itself?

A. As a *cell;* under the guidance and direction of the vital force, all growth or increase in volume and weight in all animals and vegetables takes place by the introduction of new matter from without—namely, by the development of a multitude of little cells.

Q. What is a CELL?

A. *A cell is a little membranous bladder* containing a fluid. When cells are once formed, they become modified in various ways, but their appearance always precedes the formation of circulating vessels, or any of the more complex forms of organic structure.

Q. What is the delicate GREEN SLIME which is seen on the surface of standing water?

A. The *lowest form of vegetable life;* examined under the microscope, it is but a collection of cells.

Q. What WONDERFUL PROPERTY does the living cell possess?

A. The power of *influencing chemical action.* What is called "secretion" in animals and plants is the result of the use of this function: by it the body grows, for the cell secretes or prepares its own food.

Q. Do DIFFERENT KINDS of cells produce DIFFERENT SUBSTANCES, and possess different powers in this respect?

A. They *do.* For example, one kind of cell will *decompose carbonic acid*, reject the oxygen, and preserve the carbon within its walls or

tissues; a second will produce out of the inorganic constituents of the air the sweet-smelling principle of the rose; a third will convert a portion of the blood into milk; and yet to the eye all are alike, "a collection of little wet bladders."

Q. Do we know WHY one portion of a plant should produce sugar, and another portion gum? WHY one portion of the animal system should produce blood, and another milk?

A. Under the *influence of the vital or living force*, the organs of animals and vegetables absorb oxygen, hydrogen, nitrogen, and carbon, and from these elements, in great part, are produced such products as the system or constitution of the animal or vegetable may require. Why this action takes place, we know not; neither can we combine these elements directly to form artificially any of these compounds.

The great principle of life has ever been a secret to mortals.

CHAPTER LIII.

VEGETABLE ORGANISATION AND PRODUCTION.

Q. Why do SEEDS GERMINATE and sprout?

A. Through the *agency of the vital force* which slumbers in them until called into activity through the influence of heat and moisture.

Q. Of what are all the CELLS and VESSELS of plants COMPOSED?

A. Of *vegetable tissue.*

Q. What is VEGETABLE TISSUE, or SKIN?

A. A *compound of oxygen*, *hydrogen*, and *carbon.* It is to plants what bones, flesh, and skin are to the animal body, forming the solid mass of all vegetable organs.

Q. Will you give SOME EXAMPLES of the different forms of woody tissue?

A. In the *bleached fibres* of *cotton* and *flax*, we have examples of perfectly *pure vegetable tissue* or *fibre;* common *cork*, the stones of *fruits*, the *leaves*, *stems*, and *flowers* of *plants*, the *soft pulp of the apple*, *peach*, *carrot*, &c., the *husks of grain* (bran), and the hard indigestible structure of straw, wood, &c., are all examples of vegetable tissue.

Q. What is VEGETABLE MOULD, or humus?

A. It is the product of the *decay of vegetable tissues.* When vegetable tissues, as straw, wood, leaves, &c., are exposed to the action of the common air, they absorb moisture, and become gradually brown and rotten. The chemical process which takes place is the same as when wood or other vegetable matter is burned; decay being a slow combustion.

Q. Why is the UPPER LAYER of earth in fields and gardens of a dark BROWN or BLACK colour?

A. Because it is rich in *humus*, or the products of the *decay of*

vegetable tissues. As these decay, the oxygen and hydrogen pass off into the air, while the carbon, which is black, is in a great measure left behind, and colours the earth with which it is mingled black or brown.

Q. What is STARCH?

A. The name starch is given to a *mealy substance* which is deposited in *most vegetables* at the time of ripening, from the juices with which the cells of the plants are filled.

Q. What COMMON VEGETABLE especially abounds in starch?

A. The *potato;* which consists entirely of cells filled with starch and water.

Fig. 148.

Q. When we examine starch under the microscope, what APPEARANCE does it present?

A. It is found to consist of a *multitude of little transparent rounded grains* or *globules*, giving one the idea of little eggs or seeds. The accompanying figure represents the starch globules of the potato.

Q. Why is it necessary to BOIL starch before using it for stiffening linen, &c.?

A. The starch, consisting of little granules, is *insoluble in cold water;* but when acted upon by hot water, the granules burst and allow their contents, which are soluble, to become mingled with the water. There results a kind of jelly, in which the small shreds of membranous matter composing the cell-walls float.

Starch is manufactured as follows:—

Potatoes, for example, from which most of the starch of commerce is manufactured, after being pared, are grated to a pulp. This pulp is put upon a sieve and stirred about, while, at the same time, a little stream of water is made to flow upon it. A milky liquid runs through the sieve, but the fibrous portion of the potato, the vegetable tissue, remains behind. This liquid, after a short interval, deposits a white powder, which is the starch. By the simple process of tearing up the vegetable tissue, and removing the enclosed starch by washing, this substance may be procured from a great variety of plants.

Q. Why do potatoes, beans, rice, and most of the common vegetables SWELL UP when boiled with water?

A. Because the *starch absorbs water* at the boiling temperature, which causes the *cells* to *swell*, thereby giving the vegetable a rounded appearance.

Q. What is the COMPOSITION of WHEAT FLOUR?

A. *Starch* is one of the *principal constituents* of wheat flour, as well as all other kinds of meal. The other principal constituent is a gray, tough, clammy substance, called *gluten.*

Q. To what does PASTE, made of wheat or rye flour, owe its adhesiveness?

A. In some measure to the *starch*, but principally to the *gluten* contained in it.

Q. Can starch be converted into GUM and SUGAR?

A. It *can.* *Fruits and plants effect this change naturally;* we can

also produce the change artificially, by boiling starch with a small quantity of sulphuric acid.

Q. Why are THAWED potatoes sweet?

A. Because by the *freezing action* the starch of the potato is in part *turned into sugar.*

Q. Why are apples, pears, grapes, &c. in their UNRIPE state SOUR, and in their RIPE condition SWEET?

A. In the unripe fruits mentioned *starch is present;* in the ripe fruits it is *absent;* in the process of ripening the starch is *changed into sugar*, and the fruit, losing its sour taste, becomes sweet.

Q. Why are GREEN GOOSEBERRIES, CURRANTS, &c., HARD; and RIPE ones SOFT?

A. Because they contain a large number of *little cells with thick walls;* these become *thinner from day to day*, as the fruit ripens, until they break, when the fruit becomes *soft.*

Q. What is GUM?

A. Gum is a vegetable substance, *intermediate between starch* and *sugar.* That variety of gum which is formed directly from starch is called *dextrine;* the gum which exudes from the bark of many plants has received the general name of *resin.*

Q. Why does CURRANT JUICE when boiled with sugar form a jelly?

A. Because the currant juice contains *pectine*—a gelatinous matter which abounds in many fruits. The consistence of currant and other fruit jellies is ascribed to this substance.

Q. Of what is SUGAR composed?

A. Of carbon, hydrogen, and oxygen.

The composition of sugar is identical with that of starch and gum. These different substances are supposed to owe their different properties to a diverse arrangement of their atoms. In no other way can we account for the fact of substances having the same composition differing so greatly in their properties.

Q. Is sugar a VEGETABLE substance?

A. Yes; it is found in the juice of many plants, and in the sap of several trees; but it is extracted in the greatest abundance from the juice of the sugar-cane, which is cultivated for that purpose in the Southern States of America, the West Indies, &c.

Q. Is sugar also an ANIMAL product?

A. It *is;* it exists in *milk*, imparting to it its sweet taste. In certain diseases of the body sugar is manufactured by the organs of the body from the food.

Q. What TWO GREAT VARIETIES of sugar are recognised?

A. Cane sugar and the *sugar of grapes*, or *grape sugar.* The first variety of sugar is obtained from the sugar-cane, the beet-root, and the sugar-maple; the other variety is found in fruits, especially in the grape, from whence it derives the name of grape sugar.

The latter is much less sweet than the former, an ounce of cane sugar being equal, for sweetening, to two ounces and a half of grape sugar.

Q. What is the SUGAR which often gives to prunes and raisins their WHITE coating?

A. Grape sugar.

Q. Does MOLASSES, or TREACLE, exist in the cane, or in the cane juice?

A. It *does not*, but is produced from the *crystalline sugar by the presence of acids*, and by the high temperature used in boiling: it is called uncrystallisable sugar.

Fig. 149.

THE SUGAR-CANE.

Q. What is the estimated annual production of sugar in all countries?

A. It has been estimated at four thousand five hundred and twenty-seven millions of pounds.

Q. Why do the sweet juices of fruits, when boiled down, yield always a SYRUP, and never SOLID SUGAR?

A. Because in the juices of fruits inorganic acids are always found, which convert the *grape sugar* into *uncrystallisable sugar*, or molasses.

Q. Do plants produce ACIDS?

A. Acids are formed in the *vegetable kingdom* in *great abundance*; they especially exist in unripe fruits, imparting to them a sour taste.

In the decay or destruction of vegetable matter, acids are frequently formed which do not exist naturally in the substance of the plant from which they are derived.

Q. Do we find in organised structures of plants a series of ACIDS and ALKALIES, or bases, answering to those in inorganic structures?

A. We *do:* the organic acids and alkalies are not, however, *so powerful* as the inorganic.

Q. From what SOURCES are the organic acids mostly derived?

A. From the *sap* or *juices* of *plants.* Without being corrosive, they have a pure acid taste; and none, with the exception of oxalic acid, exert a poisonous influence.

Q. Why does TANNING hides convert them into leather?

A. Hides are steeped in water, with ground bark of the oak, hemlock, or other trees; these barks contain large quantities of *tannic acid*, which combines with the skin of animals, and forms a combination which is insoluble in water and not subject to putrefaction—viz., leather.

Q. Is the process of tanning leather one requiring much TIME?

A. Some varieties of skins may be tanned in a *few days* or *hours;* but the best qualities of leather often remain in the vats containing the solution of bark for several months.

Q. Why is VINEGAR SOUR?

A. Because it contains acetic *acid.*

Acetic, from the Saxon word *æced,* "vinegar," whence also our word *acid;* that is, "like vinegar."

Q. If WINE, or BEER, be IMPERFECTLY CORKED, why does it rapidly turn sour?

A. Because air gets into the liquor, and the oxygen of the air, combining with the alcohol of the liquor, produces acetic acid, or *vinegar.*

Q. From WHAT SOURCE are the vegetable or organic alkalies, or bases, DERIVED?

A. Certain *vegetable substances*, by their singularly bitter taste and remarkable effects upon the human system, have, from a very early period, attracted attention, and have been used as valuable remedies. With the progress of chemistry it was found that the whole of these did not possess the same useful qualities, but that the greater part of them consisted of useless substances, such as woody fibre, resin, gum, &c., while the peculiar active constituents form only a small part of their weight.

Q. Why are these extractive substances called the ORGANIC ALKALOIDS?

A. Because they resemble the well-known *alkali ammonia* in many respects, and combine, like this body, with acids to form salts.

Q. To what does PERUVIAN BARK owe its efficacious qualities?

A. To the presence in it of a vegetable alkaloid—*quinine.*

Q. What is MORPHIA, or MORPHINE?

A. It is the *alkaloid* or active principle contained in *opium.*

Q. What are some of the PRINCIPAL ORGANIC ALKALOIDS?

A. *Quinine*, extracted from Peruvian bark; *morphine*, extracted from opium; *strychnine*, extracted from several poisonous fruits and barks of trees growing in South America, particularly the *nux vomica*, from which it is usually prepared; *conceine*, prepared from the hemlock; *aconitine; nicotine*, the poisonous principle of tobacco; *veratryne;* and many others less known.

Q. What are the GENERAL PROPERTIES of these substances?

A. They are *colourless* and *odourless*, but of extremely *bitter taste*. In *water* they are *insoluble*, but on the other hand they are *soluble* in *alcohol* and *ether;* even in very small doses they produce remarkable effects upon the animal system, most of them being powerful and *active poisons*.

Q. For what PURPOSES are the organic alkaloids USED?

A. They are employed exclusively *in medicine*, in which they are of the greatest importance.

Thus formerly, in ague, and other diseases of like character, it was necessary to take many ounces of "bark" to effect a cure; but now it is only required to take a few grains of quinine to eradicate the same disease. By using morphine, we obtain the soothing effects of opium, and at the same time avoid the deleterious effects of the other active principles which this drug contains.

Q. What is TEA?

A. Tea is the dried leaves of a plant which flourishes in China and Japan.

Q. When was tea FIRST INTRODUCED into England?

A. Tea was *first introduced* into England in 1610, by a Dutch merchant, who obtained it from the Chinese in exchange for dried sage.

Q. To WHAT do tea and coffee owe their PECULIAR PROPERTIES?

A. Principally to the presence of *two organic alkaloids* contained in them—"*theine*" and "*caffeine*."

Q. Why do STRONG tea and coffee produce WAKEFULNESS?

A. Chiefly owing to the *influence* produced upon the *nervous system* by the *alkaloids* which they contain.

Q. What is it that imparts to tea and coffee their PECULIAR AROMA and FLAVOUR?

A. A *volatile oil* which is extracted from the tea and coffee by the hot water.

Q. Is the use of tea and coffee INJURIOUS or BENEFICIAL to the system?

A. When used in *moderate quantities* these beverages produce a *beneficial effect* upon the human system.

The effect of these beverages may be further explained as follows:—It is known that the animal body, while living, undergoes constant decay and renovation: the labours of life waste it; the food introduced into the stomach renews it; that which is wasted passes off by the lungs, or other excretory organs, and is rejected from the body of the animal. Now, the introduction into the stomach of a minute proportion of the vegetable active principle, *theine* or *caffeine* (three or four grains per day), has the remarkable effect of sensibly diminishing the absolute quantity of wasted matter rejected daily from the system of a healthy person, living on the same kind of food, and engaged in the same occupation, under the same circumstances. In other words, by using tea and coffee containing theine and caffeine, the waste of the body is diminished; and if the waste of the body is lessened, the necessity of food to repair it will be lessened in an equal proportion. By using tea and coffee, the health and strength of the body will be maintained in an equal degree upon a smaller quantity of ordinary food. These beverages, therefore, save food, or are substitutes for it, while, at the same time, they soothe the nervous system, and consequently act upon the mind.

Q. Why do the OLD and INFIRM instinctively delight in TEA?

A. In an old person the system is enfeebled and worn out, and the stomach no longer digests enough of ordinary food to make up for the

natural daily waste of the bodily substance. The size and weight of the body, therefore, begin to diminish more or less perceptibly. At this period, *tea acts as a medicine* to arrest the waste, to keep the body from falling away so fast, and thus enable the less energetic powers of digestion still to supply as much as is needed to repair the waste of the tissues.

Q. What is it that imparts to tea its PECULIAR properties and taste?

A. The presence of *tannic acid*—the same acid which is present in *oak* and *hemlock barks.*

Q. Why is the coffee-bean VALUED in proportion to its AGE?

A. Because the coffee ripens, as it were, by keeping; so that from old coffee there is a larger amount of the *volatile oil* obtained upon which the *aroma* of the infusion depends.

Q. Does this volatile oil exist as such in the GREEN COFFEE?

A. It does *not*, but is formed during the operation of *roasting.*

Q. What RULE should be observed in the roasting of coffee?

A. The aroma of coffee is most agreeable when the heat to which it is exposed is not *greater* than is sufficient to impart a *light-brown colour to the bean.* When the roasting is carried too far, a disagreeable *odour* gradually mingles with the aroma, and lessens the value of the product.

Q. Why do some WATERS give a stronger and BETTER-FLAVOURED coffee than others?

A. Because they contain a *slight quantity of alkali;* hence it is recommended, to obtain a more uniformly strong and well-flavoured coffee, to add a little *soda* to the water with which the infusion is made.

The quantity of alkali (carbonate of soda) proper to be used for about two quarts of water, should not exceed the amount which can be taken up on the end of a penknife blade.

Q. What are the COCOAS?

A. The beverages known as cocoas are prepared from certain *oily seeds*, which are first *ground to a pulp* by passing them between hot rollers, and for immediate use are diffused through hot water.

Q. What is CHOCOLATE?

A. The *cocoa-bean* ground to a *fine paste*, mixed with sugar, and flavoured with vanilla or other substances.

Q. What PECULIAR VEGETABLE PRODUCT characterises the cocoas from tea or coffee?

A. The cocoas, like tea and coffee, contain an *aromatic oil*, and an active principle resembling theine and caffeine, namely, *theobromine;* but in addition to these they contain an abundant fatty substance known as *cocoa-butter*, amounting to more than one-half the weight of the bean. It is this substance which renders chocolate and the cocoas so nutritious and so rich an article of food.

Q. What OTHER important substances do we find in plants besides woody tissue, starch, gum, sugar, and the organic acids and alkalies?

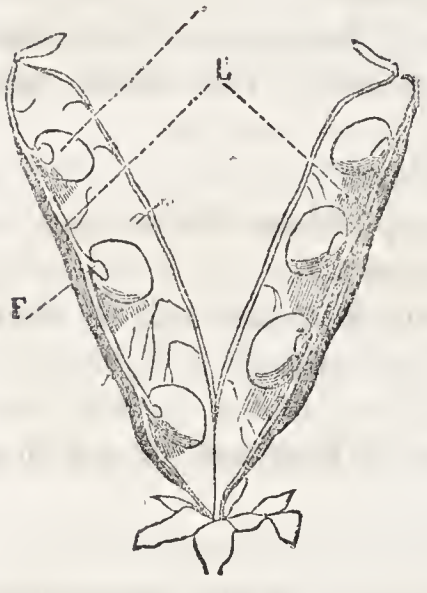
A. Substances which contain *nitrogen* and *sulphur*, and which

exercise neither a medicinal nor poisonous action upon the animal system, but are *nourishing* and *healthful*.

Q. What NAMES have been given to these substances?

A. Vegetable *albumen*, which is particularly abundant in plants used in cookery, and in oily seeds, as flax-seed, almonds, poppy-seeds, &c.; vegetable *caseine*, which exists in large quantities in leguminous plants, as peas, beans, &c.; and *gluten*, which is found in flour and meal.

Fig. 150.



Q. What do you mean by LEGUMINOUS plants?

A. Those which have their *seeds contained in a pod* or vessel, arranged in the same manner as the *seeds of peas* or *beans*. The pea (see fig. 150) and bean are considered *types* of leguminous plants.

Q. What are the DISTINCTIVE PROPERTIES of the vegetable substances which contain nitrogen and sulphur?

A. Being of a more complex nature than the other vegetable principles, they are *especially liable to decomposition*, *fermentation*, and *decay*. If, while in the act of decomposing, they come in contact with other organic substances, they cause these also to decay.

Q. Do ALL VEGETABLES contain one or more of these principles?

A. *All vegetables* contain, though not always in great quantity, *one or more* of these substances. Their office is undoubtedly to promote the growth and nourishment of the plant.

CHAPTER LIV.

FERMENTATION, PUTREFACTION, AND DECAY.

Q. What do we mean by the terms FERMENTATION, PUTREFACTION, and DECAY?

A. We mean those *changes in form* and *properties* which compound organic bodies undergo when separated from the organism which produced them, and exposed to the influence of moisture and a certain temperature.

Q. What are peculiarities of the process of decay?

A. Decay cannot take place without *air*, the oxygen of which is taken up by decaying bodies. Hence it is a process of slow combustion, in which heat is uniformly given forth, and sometimes even light.

Q. What is the DIFFERENCE between FERMENTATION and PUTREFACTION?

A. *Fermentation* is a *change* effected in the *elements of a body* composed of carbon, oxygen, and hydrogen, without *nitrogen*. *Putrefaction* is a *change effected* in the *elements of a body* composed of carbon, oxygen, hydrogen, and *nitrogen*.

Fermentation cannot take place, however, unless some decomposing body containing nitrogen is present. In fermentation, also, gaseous products are evolved which are destitute of odour; in putrefaction, the gases which are emitted possess a most offensive smell.

Q. Cider and wine, when first made, are SWEET: why do they, in the course of time, BECOME SOUR?

A. All sweet vegetable juices abound in *sugar* and some substance containing *nitrogen*. This latter, becoming decomposed, acts as a *ferment* or agent, which induces *decomposition* in the *sugar*, and causes it to pass first into alcohol, and finally into vinegar.

Q. What is a FERMENT?

A. A ferment is a substance containing *nitrogen* in a state of *decomposition*, which is able to excite fermentation in solutions of sugar; old cheese, putrefying flesh, blood, &c., are all of them ferments.

Q. What is YEAST?

A. We apply the term yeast to a species of ferment, as the *foam* of *beer*, produced by *fermentation*.

Q. Why is YEAST used in BREWING?

A. Because it consists of a nitrogenous substance (gluten) causing *putrefaction*, in a state which possesses the power of fermentation.

Q. Can you explain why it is, that a body in a state of fermentation or putrefaction should cause unlimited quantities of similar matter to pass into the SAME STATE?

A. We only *know the fact*: of the reason we are *ignorant*. The most minute portion of milk, paste, juice of grapes, flesh, or blood, in a state of fermentation or putrefaction, causes fresh milk, paste, grape juice, flesh, or blood to pass into the same condition, when in contact with them.

Q. In storing or packing fruit for future use, why is it necessary to carefully REMOVE every DECAYED SPECIMEN?

A. Because the decayed portions of one specimen will quickly *communicate decay to the fresh fruit in contact* with it, and soon the whole mass of fruit will become rotten.

Q. If in a vessel, or any other structure, one timber becomes decayed, what COURSE ought to be adopted?

A. It should be removed *immediately*, or the decomposition once commenced, will in time affect the whole structure.

Q. It sometimes happens that physicians, in dissection, are seriously poisoned by the slightest cut of a knife which has been used upon the dead body: WHY is this?

A. The knife introduces to the healthy blood, through the wound, a *minute portion of matter in the state of decomposition or putrefaction*. This acts as a *ferment*, and causes the healthy matter in contact with it to pass into the same decomposed state. The action once com-

menced, rapidly extends, until the whole body becomes affected, and death ensues. It is almost impossible to heal wounds of this character.

Q. Why is it ESPECIALLY DANGEROUS to eat fruit or meats PARTIALLY DECAYED?

A. Because the *decayed portions* of the substance eaten are liable to induce the *same condition* in the healthy organs of the stomach with which they may come in contact. Ferments of any kind appear to reproduce themselves, just as seeds reproduce seeds.

Q. What is VINOUS FERMENTATION?

A. The action or change by which *sugar becomes converted into alcohol* (spirit).

Q. When solutions of sugar are caused to ferment, what NEW COMPOUNDS are formed?

A. Alcohol and carbonic acid. The alcohol is still further changed (unless the process be checked) into *acetic* acid or *vinegar*.

Q. What BECOMES of the ALCOHOL which is thus formed by fermentation?

A. It mixes with the water, and forms the *intoxicating* part of the liquor produced, as beer, wines, &c.

Q. What BECOMES of the CARBONIC ACID which is generated by fermentation?

A. It makes its escape into the air.

Q. What is ALCOHOL?

A. The *spirit* existing in wine, beer, cider, &c., *obtained in the process of fermentation.*

Q. Of what is ALCOHOL composed?

A. 4 parts are carbon, 2 oxygen, and 6 hydrogen.

Q. What is the ORIGIN of the term PROOF SPIRIT?

A. It is derived from the old method of testing spirit, which was this: The spirit to be tested was poured over gunpowder, and ignited; if the powder exploded, the spirit was said to be *above proof;* it it did not explode, it was said to be *below proof.*

Q. What is meant at the PRESENT DAY by spirit ABOVE and BELOW PROOF?

A. If we say that spirit is ten over proof, we mean that one hundred gallons of it will require *ten* gallons of water to reduce the spirit to proof strength. So on the other hand, if we say that spirit is ten *under* proof, we mean that *ten* gallons of water must be *taken* from the spirit to raise it to proof strength.

The strength of spirit is now tested by the hydrometer.

Q. In what STATE does alcohol exist in wine, beer, cider, &c.?

A. It exists in wine, beer, cider, and other fermented liquors combined with a *large quantity of water* and some oily and other organic substances.

Q. What PROPORTION of alcohol generally exists in cider?

A. About *nine per cent.;* it thus resembles in strength the weak hock wines, or common ale.

Q. How is WINE MANUFACTURED?

A. The grapes are collected and *pressed;* the juice, which is called

must, is poured into vats situated in cellars, where, as the temperature is low, the fermentation proceeds so slowly, that it is not completed until after some months. During the fermentation the *impurities rise to the surface* in the form of *froth* or *yeast*, or settle to the bottom of the vats (lees), so that the pure wine is finally drawn off clear, ready for use.

Q. Why is it NOT needful to put YEAST into GRAPE juice in order to produce fermentation?

A. Because grape juice contains a sufficient quantity of a *nitrogenised substance* (like *yeast*) to produce fermentation.

Nitrogenised—that is, containing nitrogen.

Fermentation cannot occur unless the sugar be dissolved in a sufficient quantity of *water*.

Q. Why are some varieties of wine RED, and others YELLOW, or colourless?

A. In the manufacture of red and coloured wines, the *purple* grapes are bruised, and then fermented, together with their skins and stalks; a red colouring matter is extracted from the skins, and tannic acid from the seeds and stalks, the last imparting to the wine a peculiar taste. In the colourless wines, the grapes from which they are manufactured are often *colourless*, and the *pure juice* is alone preserved and fermented.

Q. How is SPARKLING WINE (Champagne) manufactured?

A. The fermentation is allowed to proceed in *corked-up bottles*, whereby the *carbonic acid* formed is retained in the wine.

The wines produced in Germany—the hock, &c.—are possessed of a peculiar flavour, called the *bouquet*, and a sour taste; while the wines of Southern Europe are sweet to the taste, but wanting in flavour. The cause of this difference has been explained as follows:—

The grapes growing in *northern countries*, as in Germany, contain so much nitrogenous matter (which produces the fermentation), that all the sugar is converted into alcohol, and a flavouring substance, called œnanthic ether, is also generated. In *southern countries*, in consequence of a higher temperature, the grapes are richer in sugar, but poorer in nitrogenous compounds. The latter not being present in sufficient quantity to decompose all the sugar, a part remains, and renders the wine sweet. Neither is there any of the peculiar flavouring material generated in these wines.

Q. How does the manufacture of strong beer and whisky DIFFER from that of wine?

A. Wine is manufactured from materials which contain *sugar already formed*, but the materials from which beer and whisky are produced contain *no sugar* in the outset, but *starch*.

Q. What are the MATERIALS from which beer and whisky are manufactured?

A. *Wheat*, *rye*, *potatoes*, *corn*, *barley*, or any *similar* vegetable products.

Q. Can we manufacture alcohol by fermentation directly from STARCH?

A. We *cannot;* it is necessary to first convert the starch into *sugar*, and from this we can produce alcohol by *fermentation*. This in the case of beer is effected by converting the barley used into what is called *malt*.

Q. How is BARLEY converted into MALT?

A. It is moistened with water, and *heaped up;* by which means great *heat* is produced, which makes the *barley* sprout.

Q. WHY is BARLEY MALTED?

A. Because germination *is produced* by the artificial heat; and in germination the starch of the *grain* is converted into sugar.

Q. How is starch converted into sugar in the process of fermentation?

A. When seeds, and especially barley, begin to germinate, there is formed a peculiar nitrogenised substance called *diastase*, which possesses the remarkable property of converting starch into sugar. It is through the agency of diastase that the change takes place.

Q. Is starch converted AT ONCE into sugar?

A. No; it first becomes *gum*, and then *changes to sugar.*

Q. How is BARLEY PREVENTED from GROWING in the process of MALTING?

A. It is put into a kiln as soon as it sprouts, and the *heat* of the kiln checks or *destroys* the young *shoot.* The product as it comes from the kiln is called "*malt.*"

Q. Why is not the BARLEY suffered to GROW as well as SPROUT?

A. Because plants in the germ contain *more sugar* than in any *other* state; as soon us the germ puts forth shoots, the *sugar* of the plant is consumed to support the shoot.

Q. How is MALT converted into BEER?

A. It is *mixed with water*, and a sweet solution or infusion obtained, which is called *wort.* To the wort yeast is added, which produces fermentation, the result of the fermentation being a clear liquid, which we call beer.

Q. Does MALT contain GLUTEN?

A. Yes; the infusion of malt, called "sweet-wort," contains an abundance of *gluten*, and the yeast (which converts its *sugar* into *alcohol*) converts this *gluten* into *yeast.*

Q. Why are HOPS added to beer during the process of manufacture?

A. Hops give to beer its peculiar bitter taste, and also impart body to it.

Q. How is whisky manufactured from corn, rye, or potatoes?

A. The grain or potatoes, boiled or mashed, are mixed with a portion of barley-malt and hot water, to form a paste, which is kept for a time at a high temperature. The diastase of the malt, acting upon the starch, converts it into sugar. To this mass yeast is added, and the whole left to ferment. When this fermentation is finished, the mass is placed in a still, and the spirituous principle distilled over by heat. This product is whisky.

Q. What is BRANDY?

A. Brandy is the product obtained from the *distillation of wine.* In wine countries, the lees remaining in the vats after the wine is

drawn off are generally used for this purpose, as they retain mechanically a large quantity of wine.

Q. To WHAT does brandy owe its peculiar DARK BROWN or red colour?

A. To *burnt sugar*, which is added for the purpose of imparting colour.

Q. How MUCH ALCOHOL is contained in strong brandy, rum, and whisky?

A. From *sixty to seventy per cent.*

Q. When rum, brandy, or whisky are distilled, what is the PRODUCT?

A. A stronger liquor, called "*spirits of wine*," containing a larger proportion of alcohol.

Q. What is the PRODUCT obtained by distilling SPIRITS of WINE?

A. It is called *rectified spirits of wine*, and contains from eighty to ninety per cent. of alcohol, and the balance water.

Q. When the water is entirely separated from spirits of wine, WHAT is the PRODUCT?

A. *Pure alcohol*, called *anhydrous*, or absolute alcohol.

It is difficult to remove all the water from alcohol; this can only be accomplished by mixing with it quicklime, or some other substance having a strong attraction for water, which absorbs it, and suffers the alcohol to distil over pure.

Q. What is PROOF SPIRIT?

A. A mixture of equal volumes of *rectified spirits of wine* and *water*.

Q. What are CORDIALS?

A. Cordials, for the most part, are made of *brandy*, flavoured with what are called the *essential oils* of various plants, and afterwards sweetened.

Q. To WHAT does whisky owe its peculiar ODOUR?

A. To the presence of a volatile oily substance called *fusel oil*, formed from the potatoes or grain during the process of fermentation.

Q. Is fusel oil POISONOUS?

A. It is a very *deadly poison*, especially when inhaled into the system as vapour. It often exists in chloroform, and is the cause of the accidents which have sometimes happened on respiring the vapour of this agent.

Q. How are the FLAVOURING MATERIALS, resembling the flavour of the APPLE, the PEAR, the ORANGE, &c., which have been used in confectionery for flavouring the so-called "fruit-drops," and for other purposes, prepared?

A. By mixing *fusel oil* with an *acid*, and distilling the product. A volatile substance is obtained, which dissolved in alcohol, constitutes these celebrated flavouring materials. By using a different acid, a different flavour is obtained. Thus, acetic acid gives the flavour of the pear; valerianic acid, the flavour of the apple; nitric acid, the flavour of the orange, &c.

Q. Are these flavouring materials POISONOUS?

A. They are *not*, when used in proper quantities. Ordinary confectionery, *properly flavoured* with them, is harmless; and there is reason to believe that these products, which we form artificially in

the manner described, are identical with those which nature elaborates in the fruits themselves.

Q. Is alcohol a POISON?

A. Strong alcohol acts as a poison, producing *sudden death* when swallowed; when diluted with water, as in the ordinary spirituous liquors, it produces drunkenness and disease.

Q. What is ETHER?

A. Ether is a product obtained by *distilling strong alcohol*, and *sulphuric acid.* The product is called sulphuric ether, but it does not contain sulphuric acid, nor has it any sulphur in its composition.

Q. What are the PROPERTIES of ether?

A. It is an *exceedingly light* and *inflammable* body, producing insensibility when inhaled, and readily dissolving all fatty and oily bodies.

Q. Why will ether remove SPOTS of OIL, PAINT, or GREASE from garments?

A. Because it dissolves all greasy, oily matters.

Q. What is VINEGAR?

A. Vinegar is a product formed from *alcohol.*

Q. What is ordinary TABLE VINEGAR?

A. An *acid*, called *acetic acid*, and water.

Q. How can brandy and wine be CHANGED into VINEGAR?

A. By adding *yeast* or some other substance which will *produce fermentation*, and exposing the mixture to the air at an elevated temperature. The alcohol gradually disappears, and, by combining with oxygen, is converted into vinegar.

Q. How may vinegar be made STRONGER by FREEZING?

A. When vinegar is exposed to the cold the *water* contained in it is frozen *before the acetic acid;* by *separating the ice*, we leave a *stronger* solution of the acid behind.

Q. Why do fruit preserves frequently turn SOUR?

A. Because, owing to the action of some fermenting substance present either in the fruits themselves or in the air, the sugar used in preserving is *converted into alcohol*, and the alcohol into vinegar.

Q. Why does the housewife SCALD her preserved fruits to prevent their turning sour?

A. Because fermenting substances and fermenting action are *destroyed* by a boiling temperature.

Q. Why is the FROTH on a jar of preserves an indication that FERMENTATION is going on?

A. The froth is occasioned by *little bubbles of carbonic acid gas* enveloped in the syrup; and the carbonic acid gas could only be present through the *agency of fermentation.*

Q. Why do we keep preserves, beer, cider, or other substances liable to turn sour, in a COOL place?

A. Because as the temperature gets colder, it *arrests fermentation*, though it does not prevent its renewal when the temperature is increased.

Q. Why does milk turn SOUR by KEEPING?

A. Because it undergoes a fermentation, during which "*lactic acid*" is formed, which turns the milk sour.

The lactic acid is formed from the sugar of milk by fermentation.

Q. Why does sour MILK CURDLE?

A. Milk consists of five ingredients: 1, *caseine*, or curd; 2, *butter;* 3, *sugar;* 4, *water;* 5, certain *salts.* The caseine, or curd of *sweet* milk, is like the white of an egg *before* it is boiled; but the caseine, or curd of *sour* milk, is like the white of an egg *after* it is boiled. This caseine, or curd of milk, is *thickened by acids.* When milk is sour, the *lactic acid* of the sour milk, mixing with the caseine, thickens it; in consequence of which it separates from the water, and becomes an insoluble mass; or, in other words, the milk curdles.

Q. What is BREAD?

A. It is a kind of food prepared generally from the flour of wheat mixed to a dough with water, and submitted to the action of heat to bake. This kind of bread is called unfermented or unleavened bread.

Q. What is LEAVENED BREAD?

A. It is flour mixed to a dough with water, to which is added a little leaven (or dough which has been fermented) or yeast.

Q. What EFFECT has the YEAST on the dough?

A. It *assists* in the fermentation of the dough, by which means carbonic acid is generated in the mass, and makes the bread *porous* and *light.* It is then placed in the oven, and the gas *expanding* by heat, *raises* the dough still more.

Q. Why does BAKING dough convert it into BREAD?

A. When dough formed of flour is baked, its *starch is changed into a gum* called dextrine.

A similar change is produced upon the farinaceous portion of the dough. The *yeast* (added to the dough) converts part of the starch and sugar into alcohol and carbonic acid; of these, the alcohol evaporates in the oven, and the carbonic acid forces the dough into bubbles, and, in its effort to escape, renders the bread light and full of holes.

Dextrine is a gummy matter, similar to that which composes the cells of wood (called cellulin), only it is soluble in cold water.

Q. Why is UNBOLTED FLOUR or meal more nutritious than the fine flour or meal?

A. By bolting flour or meal, we separate the *bran* and those portions of the grain adjacent to it. These parts of the grain abound in *nitrogen*, and the *nutritive value* of food depends greatly upon the *quantity* of *nitrogen* it contains.

Q. Why is unbolted flour or meal LESS DIGESTIBLE, though more nutritive, than bolted flour?

A. Because the bran contains a large quantity of *gluten*, which is not easily *soluble in water*, and is difficult of digestion.

Q. Why is bread made of unbolted flour apt to be HEAVY and "SLACK BAKED?"

A. Because unbolted flour contains *much gluten*, which retains the water obstinately, and by its tenacity *hinders* the *escape of the bubbles of gas.*

Q. What substance is it that gives to dough its great TENACITY?

A. The *gluten* of the flour. About ten pounds of gluten are contained in every hundred pounds of fine flour.

Q. How MUCH WATER is contained in well-baked wheaten bread?

A. About *forty-five per cent.*, or nearly *one-half* the weight of fresh bread, is water.

Q. Why does bread, a few days after baking, become STALE?

A. The change is merely in the *internal arrangement* of the *particles* of the bread.

It is generally supposed that the change which takes place in bread a few days after baking, whereby it becomes crumbly and dry, is occasioned by the gradual loss of water. This, however, is not the case: stale bread contains almost exactly the same proportion of water as new bread after it has become completely cold.

Q. What NEW COMPOUNDS are produced by the change called PUTREFACTION?

A. The carbon, oxygen, hydrogen, and nitrogen of the original substance (being separated by decomposition) reunite in the following manner: 1. Carbon and oxygen unite to form carbonic acid; 2. Oxygen and hydrogen unite to form water; and, 3. Hydrogen and nitrogen unite to form ammonia.

When bodies containing sulphur and phosphorus putrefy, the sulphur and phosphorus unite with hydrogen, and form sulphuretted and phosphuretted hydrogen gases.

Q. What BECOMES of these several products of putrefaction?

A. They are all elastic bodies, and escape into the air.

Water is elastic and gaseous when in the condition of vapour.

Q. What is the CAUSE of the OFFENSIVE SMELL which issues from putrefying bodies?

A. The *evolution* of ammonia, or of sulphuretted and phosphuretted hydrogen gases, all of which have pungent and offensive smells.

Q. Decaying vegetables are first of a brownish tint: why do they afterwards turn of a BLACKISH colour?

A. Because the hydrogen of the decaying vegetables is *separated from the mass* by the process of decay, and leaves a larger proportion of carbon behind.

Q. Why do BRICKS turn GREEN on being exposed for some time to the weather, especially if deprived of the rays of the sun?

A. The "green" is a moss or lichen which grows on the bricks, and thrives better in the shade than in the sun. The seeds of these lichens are supposed to be scattered by the winds.

Q. Why does UNSEASONED WOOD DECAY much more RAPIDLY than wood well seasoned?

A. Because the *albumen* which the sap contains produces a *species of fermentation*, during which the cellular tissue and woody matter are converted into *carbonic acid* and *water*.

Q. Why will solutions of salts PREVENT the DECAY of wood steeped therein?

A. Because the salts *unite* with the albumen of the sap, *coagulate* it, and prevent fermentation.

Q. Why is WOOD placed in a stream of running WATER to SEASON it?

A. Because the running water *washes away the sap*, and thus prevents *fermentation* and *decay*.

Q. Why do we pack eggs for preservation in LIME-WATER, SALT, SAWDUST, &c. ?

A. In order to *exclude* them from the *action of the air*. The air penetrates the egg through numerous minute holes or pores of the shell, by means of which it is conveyed to the young bird during the process of hatching. If these pores be closed up, by rubbing the new-laid egg with fat, or in any similar way, it will keep fresh for a long time.

Q. Why can animal and vegetable substances be preserved by immersion in ALCOHOL (spirits of wine) ?

A. Because the alcohol *extracts the watery fluids* contained in the substance, and prevents the access of atmospheric oxygen.

Q. What THREE CONDITIONS are requisite to produce putrefaction in animal and vegetable substances ?

A. It is necessary that they should be exposed to the combined influence of *air*, *heat*, and *moisture*.

Q. Why is a substance preserved from decay by DRYING, or by the EXCLUSION of AIR from it ?

A. Because by so doing we *remove* the *moisture* and *air* essential to the process of decay.

Q. Why does the SMOKING of FISH or FLESH contribute to their preservation ?

A. Because the volatile matters of the smoke, such as creosote, pyroligneous acid, and the like, effect a species of *chemical combination* with the fibre of the meat, and with the substances contained in the natural juices of the flesh, which combinations are *less liable* to decay than the substances themselves.

Q. What are the CHEMICAL SUBSTANCES which thus retard decomposition called ?

A. *Antiseptics.*

Q. What are the best AGENTS for depriving putrid and decaying animal and vegetable substances of their offensive odours ?

A. *Chloride of lime* is the most effectual agent; and *chloride of zinc* and *sulphate of iron* (green vitriol) are also exceedingly efficient. On a large scale, as in the sanitary cleansing of towns, pulverised charcoal, burnt clay, and quicklime are to be recommended.

Q. What EFFECT does the use of perfumes or the burning of pastiles have upon offensive odours ?

A. They merely *disguise* the odour, but do *not remove or destroy it.*

Q. By adopting what precautions may a person safely enter sick rooms, or visit, without risk, the most dangerous receptacles of filth ?

A. By moistening a linen cloth with vinegar, and sprinkling over it finely-powdered chloride of lime. Air breathed through this, applied to the mouth and nostrils, will enter the lungs charged with a minute quantity of chlorine, which will effectually destroy any noxious vapours or miasms that escape from diseased bodies, or from decaying animal and vegetable substances.

CHAPTER LV.

ANIMAL ORGANISATION AND PRODUCTIONS.

Q. What CHIEFLY DISTINGUISHES the life of an animal from the life of a vegetable?

A. During the life of the animal *oxygen* is incessantly *inhaled*, or drawn in; but during the life of the vegetable it is *exhaled*, or sent forth.

The food of all animals, in all circumstances, consists, with the exception of water and some salts, of organised matter; the food of vegetables is inorganic matter. Animals are distinguished from vegetables by the faculty of self-motion, and in general by the possession of senses.

Q. Is the elementary matter from which the organs of the animal body are formed, the SAME as that which occurs in the vegetable kingdom?

A. It is *exactly the same;* namely, oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, and chlorine; and the metallic substances, calcium, potassium, sodium, and iron. These must be introduced into the animal body in order that it may grow and live. The chief mass of vegetable matter consists of substances wanting in nitrogen, while animal substances particularly abound in this element.

Q. What is ALBUMEN?

A. Albumen is an *animal substance* as well as *vegetable.* It exists most abundantly, and in its purest natural state, in the *white of an egg*, from whence it derives its name (*album ovi*), which is the Latin for the white of an egg.

The serum, or fluid portion of the blood (which, after exposure to the air, is separated from the more solid part), the vitreous and crystalline humours of the eye, the brain, spinal marrow, and nerves, all contain albumen.

Q. What is the YOLK of an egg?

A. This also consists of *albumen*, but contains in addition a *yellow oil*, which imparts to it its colour.

Q. Why will MILK BURN very easily when boiled? water will not do so: EXPLAIN this.

A. 1. Because milk contains *solid organic substances* capable of burning, which water does not; and

2. Because the heat of the fire curdles the albumen of the milk, which falls to the bottom, and adheres to the boiler.

Q. Why are LAMB and VEAL more TENDER than beef and mutton?

A. Because they contain *more* albumen, and less muscular fibre.

Q. Why do LAMB and VEAL TAINT more quickly than beef and mutton?

A. Because they contain a large quantity of albumen, which is very *liable to putrefaction.*

Q. Why is meat TOUGH which has been BOILED TOO LONG?

A. Because the *albumen* becomes hard, like the white of a hard-boiled egg.

The best way of boiling meat to make it tender is this: Put your joint in very brisk

boiling water ; after a few minutes add a little cold water. The boiling water will *fix* the albumen, which will prevent the water from soaking into the meat, keep all its juices in, and prevent the muscular fibre from contracting. The addition of cold water will secure the cooking of the *inside* of the meat, as well as of the surface.

Q. Why is meat always TOUGH if it be put into the boiler before the water boils ?

A. Because the water is not hot enough to *thicken* the albumen between the muscular fibres of the meat, which therefore runs into the water, and rises to the surface as scum.

Q. Why is the flesh of OLD animals TOUGH ?

A. Because it contains *very little* albumen, and much muscular fibre.

Q. Is SALTED meat as NUTRITIOUS as fresh meat ?

A. No; because the albumen of the meat is *separated from the flesh* by the brine, as well as the alkaline phosphates, and some other substances of great value.

Alkaline phosphates are phosphoric acid combined with some alkali, such as soda, potash, magnesia, &c.

Q. Why does SALT PRESERVE meat ?

A. 1. Because it *removes* the water contained in the animal fibre, absorbing it, and leaving the meat dry;

2. Brine draws away the albumen from between the muscular fibres, which is especially subject to putrefaction;

3. The salt unites with the *muscular fibre*, and makes a new chemical compound much less subject to decay; and

4. It keeps the *air*, *flies*, &c., from the meat.

Q. Fresh flesh, over which salt has been strewed, is found, after twenty-four hours, swimming in brine, though not a drop of water has been added : WHERE has the water come from ?

A. The water has been yielded by the *muscular fibre itself;* and having dissolved the salt in immediate contact with it, and thereby lost the power of penetrating animal substances, it has on this account separated from the flesh.

Q. Why is water, containing much salt in solution, INCAPABLE of being ABSORBED by the tissues of the body ?

A. On account of a remarkable property possessed by all animal membranes, skin, and tissues—namely, an *inability of being soaked* by any *concentrated solutions of salt.* It is only when these solutions are diluted to a great extent with water, that they are absorbed by animal tissues.

Q. Why is a sensation of THIRST excited by eating food containing much salt ?

A. Because the salt *extracts water from the stomach*, and retains it. Hence a strong desire for water to restore that which has been taken from the system is experienced.

Q. Why does not the water of the ocean, when drank, ALLAY THIRST ?

A. Because it is a *solution of salt*, and when drank *absorbs water from the system* instead of imparting any to it.

Q. Why does the use of SALT BEEF produce SCURVY?

A. Because the *soluble salts are removed* from the beef by brine; in consequence of which it cannot restore to the human system those salts which are essential to *preserve the blood in a healthy state.*

Scurvy is a diseased state of the blood.

Q. Why does the USE of VEGETABLES generally PREVENT SCURVY?

A. Because they *contain the soluble salts* removed from the beef by brine, which, being *restored* by the vegetables, preserve the blood in a healthy state.

Q. What is FIBRINE?

A. It is a *compound* which abounds in both animal and vegetable substances;—the chief part of *muscular flesh* is formed of fibrine. It also exists in chyle, and enters into the composition of the blood.

Q. What is CASEINE?

A. It exists in *milk*, and constitutes the *greater part of cheese* made from skimmed milk.

Q. Does CASEINE exist also in VEGETABLES?

A. It is found in *peas*, *beans*, &c. When these vegetables are crushed, mixed with water, and strained, caseine is separated, which has all the characteristics of skimmed milk.

Q. What is GELATINE?

A. It is a jelly-like *substance*, formed by boiling animal membranes, skin, and bones. The well-known substance called isinglass and also calves'-foot jelly are familiar examples of *gelatine.* Glue is a kind of gelatine dried in the air.

Q. What PROPORTION of the beef we eat is SOLID substance?

A. Only about *one-fourth.* If a piece of beef be thoroughly dried, either in the sunshine or over boiling water, it will be so far diminished in bulk that four pounds will afford but one of dried flesh.

Q. What is the MAIN CONSTITUENT of dried flesh?

A. *Fibrine:* this substance closely resembles the gluten of plants in composition and properties, so that in comparing animal and vegetable food, we may consider them as identical.

Q. What is the chemical DIFFERENCE between BEEF and BREAD?

A. Flesh does *not contain starch*, which is so *large an ingredient* in *vegetable* products, and the proportion of *fibrine* in beef is about *three times greater* than it is in bread. Fibrine and gluten being the principal nutritious substances of beef and bread, it therefore follows that a pound of beefsteak is as nutritive as three pounds of bread. Lean fresh beef contains more water also than is found in an equal weight of bread.

Q. What is the RELATIVE NUTRITIVE VALUE of the different kinds of meat as food?

A. The relative nutritive value of the different meats for food is as follows: *beef* is the *most nutritious;* then *chicken*, *mutton*, *pork*, and *veal.*

Q. What varieties of FISH are the most NUTRITIOUS?

A. The *salmon*, the *eel*, the *haddock*, and the *herring*, in order.

Q. What VEGETABLE of ordinary consumption is the most nutritious?

A. The *cabbage*.

Q. Is there any REASON for the usual practice of cooking and eating pork and cabbage together?

A. The reason of eating these two articles of food together is that *cabbage* contains a large percentage of *gluten*, and little *oily* or *fatty* matter; in pork, a *reverse order* exists. The mixture of the two causes a better digestion than when either are eaten alone.

Q. Why do we instinctively desire to eat BUTTER or cheese with bread, FAT with cabbage, and OIL with salad?

A. An article of food, to be in every respect nutritious, must contain *gluten*, *starch*, and some variety of *fat*. When the proportion of these substances in any article of food is too small, chemistry teaches, and experience and instinct direct, that an additional quantity of the deficient substance should be added in the process of cooking, or preparatory to eating.

Thus, bread contains little fat or oil, and therefore butter or cheese is eaten with it, in order that it may be more palatable, more digestible, and more nutritious. For the same reason we eat pork and cabbage, salad and oil.

Q. The peculiar character of all chemical compounds, when brought in contact with matter endowed with life, is an aptitude and power to enter into combinations and effect decompositions. When a chemical compound of simple constitution is introduced into the stomach, or any other part of the system, what must be its EFFECT?

A. It will tend to exercise a *chemical action* upon *all substances* with which it *comes in contact*. This action is opposed by the vital principle, and the result will depend upon the strength of the respective actions.

Q. When will the chemical compound be DIGESTED?

A. When it is forced to yield to the *superior power* of the *vital action*, and exercises no chemical influence upon the living organ.

Q. When will the chemical compound act MEDICINALLY?

A. When it causes a change in the *vital principle*, without destroying it.

Q. When will the chemical compound act as a POISON?

A. When it obtains an ascendancy over the vital force, and *destroys it*.

Q. When will food act as a POISON, and produce DISEASE?

A. When it is able to exercise a chemical action by virtue of its quantity, or when either its condition or its presence *retards*, *prevents*, or *arrests* the *motion of any organ*.

Q. What is CONTAGION?

A. We apply the term contagion to that *subtle matter* which proceeds from a *diseased person or body*, and which *communicates the disease* to another person or body. Contagion differs from miasm in being the product of disease, and in reproducing itself.

Q. What is MIASM, or MIASMATA?

A. Miasm or miasmata is the *product of the decay or putrefaction of animal or vegetable substances*, and causes disease without being itself reproduced. Contagion occasions disease in the same way that yeast excites fermentation. Miasm often acts, by its chemical properties merely, as a poison.

Q. Why are contagious diseases sometimes communicated to individuals who merely APPROACH the VICINITY of diseased persons, but do not come in CONTACT with or even see them?

A. Because the *air* itself, which has been in contact with the diseased persons, *carries with it the seeds or germs of infection*, and thus communicates disease, sometimes at great distances.

Q. Why are not ALL persons affected alike when exposed to similar contagious diseases?

A. Contagious matter is not capable of producing disease, unless a *compound is present in the system capable of being decomposed by contact* with the exciting body.

Q. What do we mean by SUSCEPTIBILITY to contagion?

A. We mean that the *blood* of a person *contains substances* by the decomposition of which the exciting body or contagion can be *reproduced.* If these substances are not present, and if the system be perfectly healthy, contagion will fail to produce disease.

Q. When is disease called MALIGNANT, and when BENIGNANT or MILD?

A. All disease is occasioned by changes or transformations, which take place in organs in a manner different from what occurs in ordinary healthy action. If these transformations are perfected on constituents of the body which are *not essential to life*, without other parts taking a share in the decomposition, the form of disease is mild; when these changes affect the organs *essential to life*, the disease is called malignant.

CHAPTER LVI.

FATS, OILS, GUMS.

Q. What is the CHEMICAL CONSTITUTION of a FAT or an OIL?

A. All fats and oils consist of *an acid united to a base.* Every simple fat contains a *peculiar acid*, but the *base* in all fats and oils is *the same.* Thus stearine is composed of stearic acid united to glycerine; this combination makes up the great bulk of tallow; in oil we have oleic acid united to glycerine, the combination forming the bulk of the fixed oils.

Q. What is SOAP?

A. Soap is a combination of some one of the *fat acids* with an *alkali.*

Q. How is SOAP manufactured ?

A. The fat or oil is *heated in the presence of potash or soda.* These strong bases displace the weak base glycerine, and combine with the fat acids, forming combinations of fat acids with soda (soda or hard soap), or of fat acids with potassa (potassa or soft soap).

Q. Why is soap SOFT when made with potash ?

A. Because in soft soap the *glycerine*, dissolved in water, and formerly combined with the fat acid, remains *mechanically mixed* with the soap, and renders it soft and semi-fluid. In *hard* soap, made with soda, the glycerine and the water are *separated from the soap* by the action of *common salt.*

Q. How does COMMON SALT separate glycerine and water from soap ?

A. Soap is *insoluble in salt water.* The soap-boiler takes advantage of this to make his soda soaps hard, by adding to the mixture of soap, *glycerine* and *water*, a solution of salt. The soap, not being soluble in salt water, immediately *separates* from the water and the glycerine dissolved in it, and floats upon the surface. In this situation it may be removed, and the waste lye, water, salt, and glycerine suffered to run to waste.

Q. What TWO important PROPERTIES do soaps possess ?

A. 1. They *dissolve fats* and *oils ;* 2. By mixing with much water, a *part of the alkali* contained in them is *set free*, leaving an acid salt ; that is, a combination in which the proportion of acid is greater than that of the base. The *alkali* dissolves most *organic substances*, and the fat acid causes the dissolved matter to *wash away easily.*

Q. How is the peculiar MOTTLED appearance of CASTILE soap produced ?

A. By colouring the soap with *oxide of iron.*

Q. What is a LINIMENT ?

A. *Soap* dissolved in *alcohol*, forming a tincture of soap.

Q. Why is it impossible to WRITE on GREASY paper ?

A. Because grease has *no affinity for water or ink*, and therefore will not mix with it.

Q. Why is MUTTON-FAT, &c., SOLID, and NOT liquid ?

A. Because fat contains a predominance of *solid* stearine, and only a very small quantity of the *liquid oily* substance called *oleine.* On the other hand, oil contains more of the *liquid oleine*, and less of the solid matter called *stearine.*

Q. What is the DIFFERENCE between a fat and an oil ?

A. A fat is *a compound of hydrogen* and *carbon* which is *solid* at *common temperatures ;* an oil is a compound containing the same elements which is *fluid* at *common temperatures.*

Q. Into what TWO great CLASSES do we divide fats and oils ?

A. Into *animal fats* and *oils*, the products of animals ; and into *vegetable fats* and *oils*, the products of the vegetable kingdom.

Q. What constitutes the distinction between LARD and TALLOW?

A. We apply the term lard to those animal fats which at common temperatures have a *soft, unctuous consistency*, and tallow to those which *remain hard.*

Q. From the fats of what SPECIES of ANIMALS do we extract LARD?

A. From the fats of animals that are *carnivorous*, or such as will feed on flesh; and also from the fats of birds.

Q. From the fats of what ANIMALS do we extract TALLOW?

A. From the fats of those animals which *ruminate*, or chew *the cud.* The fats of vegetables are mostly liquid.

Q. In what PARTS of the vegetable are the fats most ABUNDANT?

A. In the *fruit*, particularly in the *seeds of the plant.* The olive-tree only contains oil in the *fleshy integuments of the fruit.* As a rare exception, oil is sometimes found in the roots of plants.

Q. What is TRAIN OR FISH OIL?

A. The oil obtained from the *blubber of the right whale;* also from *seals*, *porpoises*, and other fish.

Q. Why does whale oil possess such a DISAGREEABLE ODOUR?

A. Whale oil, when melted out from the blubber at a moderate heat, has a yellow colour, and a *slight odour* which is *not disagreeable;* but that which is obtained by strong heat, or from the blubber that has become putrid, is of a *dark-brown colour*, and has a very disagreeable odour.

The action of the heat, or the decomposition of blubber, generates a peculiar product, called "phocenic acid," which imparts to the oil its nauseous odour.

Q. Why do we apply the terms WINTER-STRAINED and SUMMER-STRAINED oil to different varieties of fish oil?

A. Oil extracted or clarified in cold weather is not so liable to *congeal* as that extracted during the elevated temperature of the summer months.

Q. What is SPERMACETI?

A. The *cavities* of the *head* of the *sperm* whale are filled with a *peculiar fat*, which, when taken out, immediately begins to deposit small crystalline particles—*spermaceti*, in large quantities. This, when pressed and purified, constitutes the spermaceti of commerce.

Q. What is "NEAT'S-FOOT" oil?

A. The oil extracted from the *feet of oxen.* It is chiefly used by curriers in softening leather.

Q. Why do we employ FATS for greasing leather, harness, shoes, &c.?

A. Because they penetrate into the interior of these substances, and *remain soft* for a long period, thus rendering the leather supple and flexible.

Q. Why does OIL become THICK in WINTER-TIME?

A. 1. Because it is *condensed by the cold*, and rendered more solid; and

2. Because the "*stearine*," which is held in solution in warm

weather, is *separated by the action of the cold*, and deposited as a thick, white, and almost solid substance.

Q. Why does CHURNING cream convert it into BUTTER?

A. Cream is the fat or butter of *milk* contained in little globular cases of albumen; by churning, this film or envelope of albumen is *broken*, and the butter or fat *set free*.

The globules are invisible to the naked eye, but may be distinctly seen floating about in milk by means of a tolerable microscope.

Q. Why do the fats and oils FLOAT upon water?

A. Because their *specific gravity is less than water.*

Q. Why does cream RISE to the surface of milk?

A. The cream of milk is composed of *little globules of oil.* The rest of the milk consists of water containing albumen, caseine, and sugar. The oily part, constituting the cream, having a *less specific gravity*, rises and floats upon the surface of the watery portion.

Q. Why does cream rise more freely from milk in a BROAD, FLAT dish, than from milk in a deep and narrow vessel?

A. Because cream cannot rise through a *great depth* of milk. If, therefore, milk is desired to retain its cream for a time, it should be put into a deep, narrow dish; and if it be desired to free it most completely of cream, it should be poured into a broad, flat dish, not much exceeding one inch in depth.

Q. Why will cream rise upon milk more readily in HOT weather than in cold?

A. The separation of cream is *hastened* by a *higher* and retarded by a lower temperature. At the usual temperature of the dairy, 50 degrees F., all the cream will probably rise in thirty-six hours; but at 70 degrees it will rise in half that time. When the milk is kept near the freezing point, the cream will rise very slowly, because it becomes nearly solid.

Q. What is RESIN?

A. Under the term resin we include all the *products* of the *sap* of the *trees* belonging to the genus *pine*. The word resin generally indicates the sap of the ordinary varieties of white and yellow pine; the distinctive name for the white and yellow pine-tree sap is turpentine.

Q. What is oil or spirits of TURPENTINE?

A. The *volatile oil obtained* by distilling the resin of the *pine*.

Q. What is ordinary RESIN, such as is used in the manufacture of gas?

A. It is the *product left after the oil of turpentine* has been distilled from the sap or resin of the pine.

Q. What is CAMPHINE?

A. *Pure spirits or oil of turpentine.*

Q. What is the composition of BURNING FLUID?

A. Burning fluid is for the most part a mixture of *spirits of turpentine and alcohol.* Other oils and resins are not unfrequently mixed with it.

Q. What is STEARINE ?

A. Fats are not homogeneous (of the same nature) bodies, but are composed of a mixture of several more simple kinds of fat, into which, without being chemically decomposed, they may be divided. Most fats may, by chemical or mechanical action, be divided into a solid fat and a fluid fat. To the first we apply the term *stearine*, to the last, *oleine*.

Q. In what FATS does stearine especially PREDOMINATE ?

A. In the *hard varieties* of *tallow* and *lard*. In mutton-tallow, the quantity of stearine is very great.

Q. In what FATS does oleine especially PREDOMINATE ?

A. In the *oils;* and it is to the abundance of this principle in their constitution that they owe their fluidity.

Q. Why do we call some oils DRYING OILS ?

A. All oils absorb oxygen from the air, and become thereby thicker, but there is an essential difference between the various kinds; drying oil becomes perfectly *hard* and *dry*, while an unctuous oil will always remain soft and sticky.

Q. What are some EXAMPLES of the drying oils ?

A. Most vegetable oils are drying oils; the *linseed*, or flax-seed oil, the oil of the *hempseed*, *poppy oil*, *castor oil*, &c.

Q. What is VARNISH ?

A. Varnishes are divided into three kinds, according to the material in which a resinous substance is dissolved; these are *spirit varnishes*, in which the solvent is alcohol; *essential oil varnishes*, in which a volatile oil, commonly oil of turpentine, is used; and *oil varnishes*, which consist of a resin dissolved in a drying oil.

Q. What is OIL-CLOTH ?

A. *Coarse cotton or linen cloth* covered with coloured *varnishes.*

Q. What is OIL-SILK ?

A. Simply *varnished silk.*

Q. What is "JAPANNING ?"

A. *Varnishing in colours.*

It is, therefore, a species of painting. It is most easily executed upon wood or metal, or such other substances as retain a determinate form, and are capable of sustaining the operation of drying the varnish. Japanning requires to be executed in warm apartments, and the articles are warmed before the varnish is applied to them. Ovens are also employed to hasten the drying of the work.

Q. What is "LACQUERING ?"

A. Lacquering consists in the application of *transparent varnishes to metals*, to prevent their tarnishing, or to give them a more agreeable colour.

When the colour of the metal to be lacquered is to be changed, the varnish is tinged with some colouring matter; but where preservation from rust or tarnish is the sole object, any of the transparent varnishes will answer, the best and hardest being used where the greatest durability is required.

Q. What is CAMPHOR?

A. Camphor is a *solid, white gum*, obtained from the *camphor-tree* growing in Japan and the East Indies.

Q. What is LAC?

A. A *resinous substance* found on several different kinds of trees in the East Indies, and produced by the puncture of insects. *Shell-lac* is *refined lac.*

Q. What is SEALING WAX?

A. Ordinary red sealing wax is a mixture of *shell-lac, turpentine*, and *vermilion.* The vermilion is only used as a colouring material, and, by using other pigments, other colours can be imparted to the wax.

Q. What is AMBER?

A. A *fossil resin.* It is chiefly found in the earth, on the coast of the Baltic Sea, or floating on the water, and in some coal-mines. It is supposed to have been derived from the forests of a primeval age, which have been submerged by floods of water.

Q. What is ASPHALTUM?

A. A *mineral resin*, found in many parts of the world, particularly in the vicinity of the *Dead Sea* in *Palestine*, and in the West Indies. It is undoubtedly a product of coal, which has been acted upon in the interior of the earth by volcanic fires.

Q. What is NAPHTHA?

A. A *mineral oil*, which flows from the ground. It collects upon springs and lakes, particularly in the United States.

Q. What is CAOUTCHOUC, or INDIA-RUBBER?

A. A *gum resin*, which flows from various species of the *Ficus* (fig-tree), in South America and Africa. It hardens in the air into a white, elastic mass, insoluble in alcohol and water.

Q. Why has the India-rubber of commerce a dark or BLACK COLOUR?

A. Because it is *dried in smoke*, which penetrates the gum and discolours it.

Q. What substances DISSOLVE India-rubber?

A. *Ether, oil of turpentine, naphtha*, or *oil of coal tar.*

Q. What is COAL TAR?

A. Coal tar is a *black, pitchy substance*, which is formed in the *condensing apparatus of gas-works.* The gas formed from coal deposits, on cooling in the condensers, a variety of oily, resinous bodies, which collectively have received the name of coal tar.

By distillation, coal tar furnishes a number of volatile oils, one of which (benzole) is a powerful solvent for India-rubber.

Q. How is India-rubber VULCANISED?

A. By *intimately mixing it with sulphur*, a compound is formed which resists a high degree of heat, and is at the same time very elastic.

Q. Why has the common BAR SOAP a YELLOW COLOUR?

A. Because it contains a certain amount of *resin*.

Q. Of what are the common WASHING FLUIDS composed?

A. Of solutions of the *caustic alkalies*.

CHAPTER LVII.

PERFUMES AND ODOURS.

Q. From what source do we derive most of the SUBSTANCES used in PERFUMERY?

A. From the *vegetable kingdom*.

Q. Do we derive any perfumes from the ANIMAL KINGDOM?

A. A *few* of the substances employed, either as perfumes or as ingredients of perfumery, are animal products; the principal of these are *musk*, *civet*, and *ambergris*.

Q. What is MUSK?

A. Musk is a substance secreted by a *ruminating animal* of the *deer family*, inhabiting the mountainous portions of Central Asia. When fresh, it is a *soft*, reddish-brown mass; the musk of commerce is in the form of dark, rounded grains; it is one of the most penetrating, powerful, and lasting of odoriferous substances.

Q. What is CIVET?

A. A *secretion*, somewhat *resembling musk*, obtained from the *civet cat*, an animal found both in Asia and Africa.

Q. What is AMBERGRIS?

A. An *odoriferous substance*, which is found floating on the *sea* in some portions of the Indian Ocean, and also off the coast of South America. It is believed to be a secretion of the *sperm whale*, in which animal it has sometimes been found.

Q. What is the APPEARANCE of ambergris?

A. When fresh it is *solid*, *grayish*, *streaked*, or *mottled* in appearance, and somewhat *soft*. It has a strong, agreeable odour, somewhat resembling musk, and a fatty taste.

Q. What DISTINGUISHING PROPERTY have all the animal odours?

A. They are remarkable for their *permanence* and *durability*. An article of dress, scented with ambergris, musk, or civet, will retain its odour even after it has been washed.

Q. Do we derive any pleasant smells, or odours, from the MINERAL kingdom?

A. The odours or smells purely derived from the mineral kingdom are more or less *disagreeable*.

Q. Into what THREE CLASSES may the vegetable odours be divided?

A. Into the *volatile oils*, extracted from odoriferous plants; the *fragrant resins*, *camphors*, and *balsams*; and the *volatile ethers*.

Q. To what is the ODOUR of most plants and flowers to be ASCRIBED ?

A. To the presence of a *volatile oil*, which gradually evaporates.

Q. Does this volatile oil exist in any CONSIDERABLE QUANTITY in plants ?

A. It is *diffused and diluted* in the system of the plant to a most *incredible extent.* Thus, in one hundred pounds of fresh roses, or orange-blossoms, there is scarcely one ounce of volatile oil

Q. How are the volatile oils OBTAINED from plants ?

A. Generally by *distillation.* When the parts of a sweet-smelling plant are distilled with water, an oil passes over along with the steam, and floats on the surface of the water, which condenses in the receiver. In this way are obtained the oils of roses, lavender, cinnamon, peppermint, lemon, orange, wintergreen, &c.

Q. What is ROSE-WATER, LAVENDER-WATER, and the like perfumed liquids ?

A. Simply *water*, in which a portion of the *volatile oil* which is collected by distillation is retained.

Q. Is the odoriferous principle UNIFORMLY DIFFUSED over the whole plant ?

A. It is *not:* in the *mint* and *thyme* it is in the *leaves* and *stem;* in the *sandal* and *cedar* trees it is in the *wood;* in the *cinnamon*, in the *bark;* in the *rose*, *violet*, &c., in the *leaves* of the flower; in the *vanilla*, *anise*, and *caraway*, it is in the *seed;* and in the *ginger*, *sassafras*, &c., it is in the *root.*

Q. What is a POMATUM ?

A. The name is given by the French to *fats perfumed* with the *odour of flowers.* The flowers are moistened with the fat, and, after lying a little while, are submitted to pressure; or they are put into hot water with the fat, and the mass well shaken together; after which the fat, rendered fragrant, is removed.

Q. What is the CHEMICAL COMPOSITION of the VOLATILE OILS ?

A. The volatile oils which constitute the odoriferous principles of most plants are composed of two elementary bodies, *carbon and hydrogen.* And what is very remarkable, many of them, which seem to be entirely distinct bodies, consist of these two elements united together in exactly the same proportion.

Q. What is the composition of OIL of TURPENTINE ?

A. One hundred pounds of oil of turpentine consists of *eighty-eight and a fourth pounds of carbon, united to eleven and three-fourth pounds of hydrogen.*

Q. What is the chemical composition of the OIL of LEMONS, ORANGE, ROSEMARY, ROSES, COPAIBA, QUEEN OF THE MEADOW, and many other like oils ?

A. The chemical composition of all these different oils is the *same as that of oil of turpentine*, viz. $88\frac{1}{4}$ parts of carbon united to $11\frac{3}{4}$ parts of hydrogen. So far as composition is concerned, they are all identically the same bodies.

Q. If these different volatile oils are all alike in composition, to WHAT can we ascribe their DIFFERENCE in PROPERTIES ?

A. It is supposed to be owing to the difference in which the *minute*

molecules or atoms of carbon and hydrogen are grouped and *arranged* around each other.

Q. What NAME do we apply to bodies thus differing in properties, but agreeing in composition?

A. *Isomeric bodies.*

Q. Can any of the ESSENTIAL, odoriferous OILS be formed ARTIFICIALLY?

A. *Oil of cinnamon* has been manufactured artificially, and there is reason to expect that all the others will ultimately be formed or imitated by chemical art.

When benzole, an oily product of coal tar, is mixed with nitric acid, a product is formed which resembles, in odour and other properties, the oil of bitter almonds, and is now extensively used as a substitute in perfumery for the costly and genuine article.

Q. What is the CHEMICAL COMPOSITION of the camphors, balsams, resins, &c.?

A. They are principally composed of *carbon* and *hydrogen*, but differ from the volatile oils in containing a proportion of *oxygen*.

Q. What is it that gives to well-made HAY its peculiarly SWEET ODOUR?

A. The presence of a *fragrant resin*, called *coumarin*, which exists in a variety of sweet-smelling grass (*anthoxanthum odoratum*).

Q. What is the ORIGIN of most of the unpleasant odours?

A. The greater number of the smells we dislike, as well as those which are agreeable, have their origin in the *vegetable kingdom*. The principal unpleasant odours of the mineral kingdom are sulphuretted hydrogen, sulphurous acid, hydrochloric acid gas, chlorine and some of its compounds, and some of the bituminous oils and compounds.

Q. What is it that imparts to the ONION and GARLIC their peculiar and disagreeable ODOUR?

A. A *volatile oil*, similar in composition to the fragrant oils, united to sulphur.

Sulphur always exists in the onion, and the odoriferous substance which this vegetable contains is called the *sulphuret of allyle*. The bad odour of the breath, after eating onions and garlic, is caused by a constant presence of a small quantity of this oil in the air we exhale from our lungs.

Q. What is ASSAFŒTIDA?

A. It is the *juice* or resin of an Asiatic plant. It contains the same smelling substance, the *sulphuret of allyle*, as the onion.

It is also a curious fact that the horseradish, the mustard, and several other plants of like character, contain the same oily compound which characterises the onion, the leek, the garlic, and assafœtida. Mustard, in particular, owes its peculiar penetrating odour, blistering properties, and burning taste, to the presence of the oil allyle, combined with cyanogen, as well as with sulphur.

Q. Will the ORGANS of SMELL always give us evidence of the presence of putrid, volatile, infectious matter in the atmosphere?

A. They will *not* give us this evidence, and *cannot be relied on.* The condor and the vulture will detect the presence of decaying matter in the atmosphere, emanating from a putrid substance many miles distant, when to man the air seems perfectly pure. Because we do not perceive an unpleasant odour from the vaults of churches

and cemeteries, it is no evidence that the atmosphere is at any time free from infectious matter.

As an evidence of the effect which very minute quantities of volatile substances may produce in the air, Dr. Carpenter states "that a grain of musk has been kept freely exposed to the air of a room, of which the doors and windows were constantly open, for a period of ten years, during all which time the air, though constantly changed, was completely impregnated with the odour of musk; and yet at the end of that time the particle was found not to have sensibly diminished in weight."

Q. In preparing perfumery, is one SINGLE OIL, or odour, relied upon solely to produce the given effect?

A. No; it is seldom that a single oil, or the fragrant portions of a single plant, are relied on to produce any delicate perfume.

"The art of the perfumer consists in *combining* the odoriferous principles of many flowers, or in mingling together many volatile essences, in such a manner as to produce a more agreeable perfume than any single plant or essence can be made to yield. In this way the *huille de mille fleurs* (oil of a thousand flowers) professes to be made; and the receipt for the popular 'Eau de Cologne,' called the perfection of perfumery, depends for its excellency on the same principle."

Q. To what have the various odours been COMPARED?

A. To *notes in music.*

"Some blend easily and naturally with each other, producing a harmonious impression, as it were, on the sense of smell. Heliotrope, vanilla, orange-blossoms, and the almond blend together in this way, and produce different degrees of a nearly similar effect. The same is the case with citron, lemon, vervaine, and orange, only these produce stronger impressions, or belong, so to speak, to a higher octave of smells. Again, patchouly, sandal, and others, form a third class. It requires, of course, a nice or well-trained sense of smell to perceive this harmony of odours, and to detect the presence of a discordant note. But it is by the skilful admixture, in kind and quantity, of odours producing a similar impression, that the most delicate and unchangeable fragrances are manufactured. When perfumes, which strike the same key of the olfactory nerve, are mixed together for handkerchief use, no idea of a different scent is awakened as the odour dies away; but when they are not mixed upon this principle, perfumes are often spoken of as becoming sickly and faint, after they have been a short time in use."—*Johnson.*

Q. Can ART produce odours MORE OFFENSIVE than any derived from NATURAL SOURCES?

A. The researches of chemists have made known the composition of compounds which are *inconceivably disgusting;* so much so as to bear no comparison with any natural unpleasant odours. The element *selenium* forms, with hydrogen, a compound gas, one single bubble of which, in an ordinary sized room, produces on all that breathe it the usual symptoms of a severe cold and affection of the throat, lasting several days.

Q. What are examples of OFFENSIVE ARTIFICIAL ODOURS?

A. We are acquainted with a *compound of arsenic*, called *kakodyle*, which, when combined with cyanogen, the basis of Prussic acid, forms an odour which is inconceivably fœtid, and when inhaled produces *instant death.* Another substance, called *mercaptan*, is possessed of a most offensive, penetrating, and concentrated odour of onions, which adheres obstinately to all bodies with which it comes in contact.

PHILOSOPHY OF MANUFACTURES.

Q. What is to be understood by the term MANUFACTURES?

A. Originally, this word signified the various *products of hand-labour* (from the Latin *manus*, a hand, and *facere*, to make); but in the changes of language it has come to signify the opposite of its real meaning, and now denotes every extensive product of art which is *made by machinery*, with *little or no aid from the human hand.*

Q. What is now considered the most PERFECT MANUFACTURE?

A. That which *entirely does away with manual labour.*

Q. What is the END and OBJECT of all manufacturing processes?

A. To *modify* the *texture*, *form*, or *composition* of natural objects by *mechanical* or *chemical forces*, acting either separately, combined, or in succession.

CHAPTER LVIII.

NATURE OF FIBROUS SUBSTANCES.

Q. Into what TWO great CLASSES are the FIBRES used for textile purposes divided?

A. Into fibres the produce of the *vegetable kingdom*, as *cotton*, *flax*, and *hemp;* and fibres the products of the *animal kingdom*, as *silk*, *wool*, and *hair.*

Q. Into what THREE VARIETIES may vegetable fibres be distinguished?

A. Into *capsular fibres*, *cortical fibres*, and *foliaceous fibres.*

Q. What are CAPSULAR FIBRES?

A. Capsular fibres are those obtained from *pods* or *capsules*, as the fibre of the *cotton.*

Fig. 151.

COTTON PLANT—POD AND FLOWER.

Q. What are CORTICAL FIBRES?

A. Fibres obtained from the cortex or *bark of the stems of plants. Flax* and *hemp* are the types of fibres of this character.

Q. What are FOLIACEOUS FIBRES?

A. Fibres obtained from the *leaves* (folia) of plants, and not from the stalks or stems. The fibres known as *manilla* and *sisal hemp* are the types of fibres of this character.

Q. Into what TWO great CLASSES may all flowering plants be divided?

A. Into *endogenous* plants and *exogenous* plants. Plants belong to one of these two classes, according to their manner of growth and the character of their stems.

Fig. 152.

Q. What is an ENDOGENOUS plant

A. An endogenous plant (from two Greek words, *endon*, within, and *gennao*, I generate) receives its growth by matter *deposited from within itself.* Its stems are properly stalks, and are not covered with bark. Their leaves have also parallel veins. Fig. 152 represents a section of the stem of an endogenous plant.

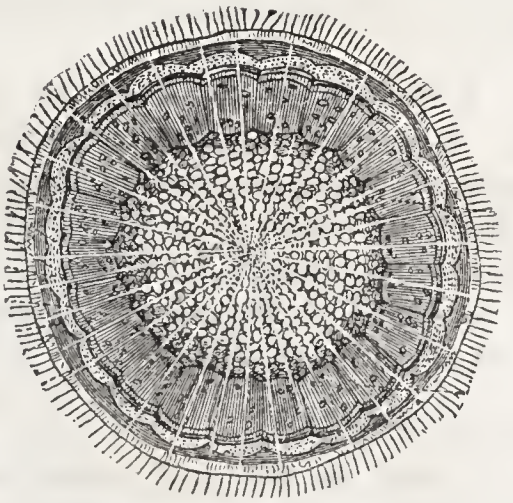
Q. What are some EXAMPLES of endogenous plants?

A. The *Indian corn*, the *sugar-cane*, the *common flag*, the *cactus*, the *lily*, the *pipe-apple*, the *palm*, the *agave*, and the *palmetto.*

Fig. 153.

EAR OF INDIAN CORN.

Fig 154.



SECTION OF A BRANCH.

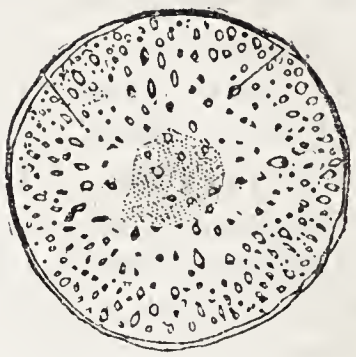
Q. What is an EXOGENOUS PLANT?

A. An exogenous plant (from *exo*, without, and *gennao*, I generate) is one that receives its growth by the *deposition of woody matter on the outer surface.* The stems of exogenous plants are properly trunks, conical and branched, and covered with bark. Fig. 154 shows the appearance of the section of a branch.

Fig. 155.

HORIZONTAL SECTION OF AN EXOGEN.

Fig. 156.



HORIZONTAL SECTION OF AN ENDOGEN.

Q. If you cut a trunk of an EXOGENOUS plant across, what will be the APPEARANCE of the SECTION ?

A. It will exhibit *concentric circles of bark and wood*, hardest at the centre, and softest at the circumference, with rays called "medullary rays," extending from the centre to the young external wood. In figs. 155 and 156 we have the representation of a section of the trunk of an exogenous plant and of an endogenous plant.

Q. If you cut a stalk of an ENDOGENOUS plant across, what will be the APPEARANCE of the SECTION ?

A. It will exhibit a *surface* of porous materials, softest at the centre, hardest at the circumference, and without bark.

Q. What are EXAMPLES of EXOGENOUS plants ?

A. Most of our *forest trees*, and the *flax* and *hemp*.

Q. How can the AGE of an EXOGENOUS tree be learned from an examination of a section of the trunk ?

A. A section of the trunk of an exogenous tree, as is represented in the foregoing figures, exhibits *concentric rings* or *circles*. The distance between any two of these rings represents the growth of the tree during a *single year;* by counting the number of rings we obtain the age of the tree. It is to be remembered that each year a new layer of wood is deposited between the previous formation and the bark in all trees of this class.

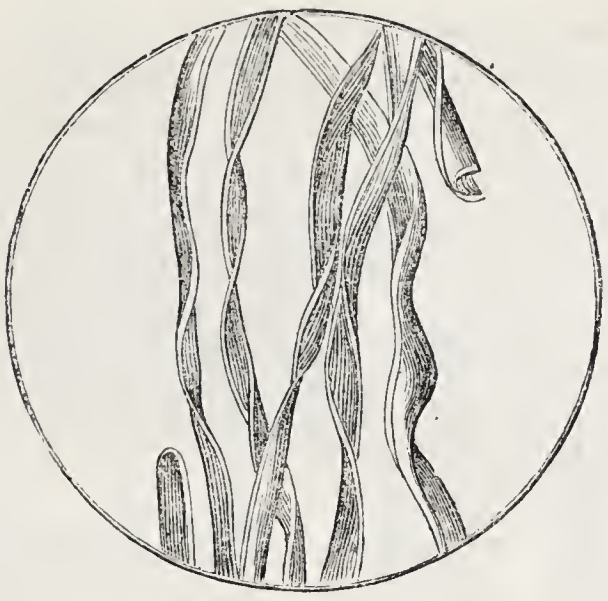
Q. What is COTTON ?

A. Cotton is the *soft*, *white*, *tubular fibre* which is found in the *capsule* of the *gossypium*, or cotton-shrub, adhering to the seeds.

Q. When we examine a fibre of cotton under a microscope, what APPEARANCE does it present ?

A. It has the appearance of a *flattened tube* or *ribbon*, without joints, each fibre being perfect and entire in itself, with pointed or rounded ends. (*See fig.* 157.)

Fig. 157.



FIBRES OF COTTON.

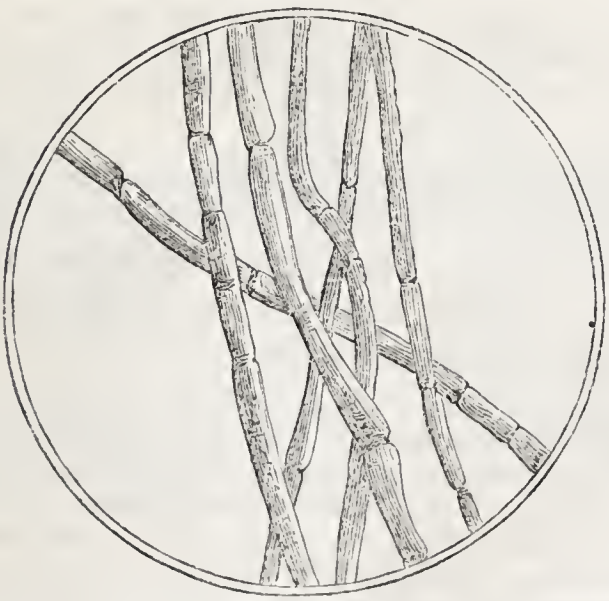
Q. When we speak of the STAPLE of cotton, what is to be understood?

A. By the staple of cotton we mean the *length of the fibres.* There are several species of cotton, in some of which the fibres are short, as the short-staple cotton; and in others it is long, as in the Sea-Island or long-staple cotton.

Q. Does the USE of cotton, as a material for textile purposes, appear to have been KNOWN to the ANCIENTS?

A. Cotton appears to have been *little known to the ancients*, although the inhabitants of India have been accustomed to its use from very remote time. It was *unknown to the Egyptians*, and also to the *Jews.* On the discovery of America the cotton manufacture was found to be in an advanced state among the *original inhabitants* of that country.

Fig. 158.



FIBRES OF FLAX.

Q. What is the MOST IMPORTANT VEGETABLE FIBRE now used for the fabrication of textile products?

A. Cotton. The amount consumed in England in a single year being upwards of eight hundred millions of pounds.

Q. How do the FIBRES of FLAX and HEMP differ from those of cotton?

A. The fibres of flax and hemp consist of *long, capillary threads* of *woody texture*, bundled together in parallel directions, which are easily separable into shorter and more minute filaments. When examined under the microscope, what to the eye alone appears to be a single flax fibre, is found to consist of a number of shorter fibres overlapping each other, and fastened together by rings of fibrous matter. (*See fig.* 158.)

Q. Have flax and hemp any STAPLE?

A. They have *not.* The fibres are all of *different lengths.*

Q. In what MANNER are the fibres of flax and hemp arranged in the stems of their respective plants?

A. The stems of the flax and hemp plants consist essentially of a *woody core*, with a *sheath of fibrous matter surrounding it* (the hemp and flax fibre), the whole cemented together by a peculiar sort of *vegetable glue*, which binds the fibre and the woody core into one solid stem.

Q. In the preparation of flax and hemp fibres, what OBJECT is sought to be ATTAINED?

A. In the preparation of flax and hemp, the great object to be attained is the *removal* of the *vegetable glue*, so that the fibrous part, being no longer bound together, may be easily separated from the woody part of the stem.

Q. How is this ACCOMPLISHED?

A. Usually by *steeping* the stems of the flax and hemp *in water*, or by *exposing them* on the ground to the joint influence of *air* and *moisture.*

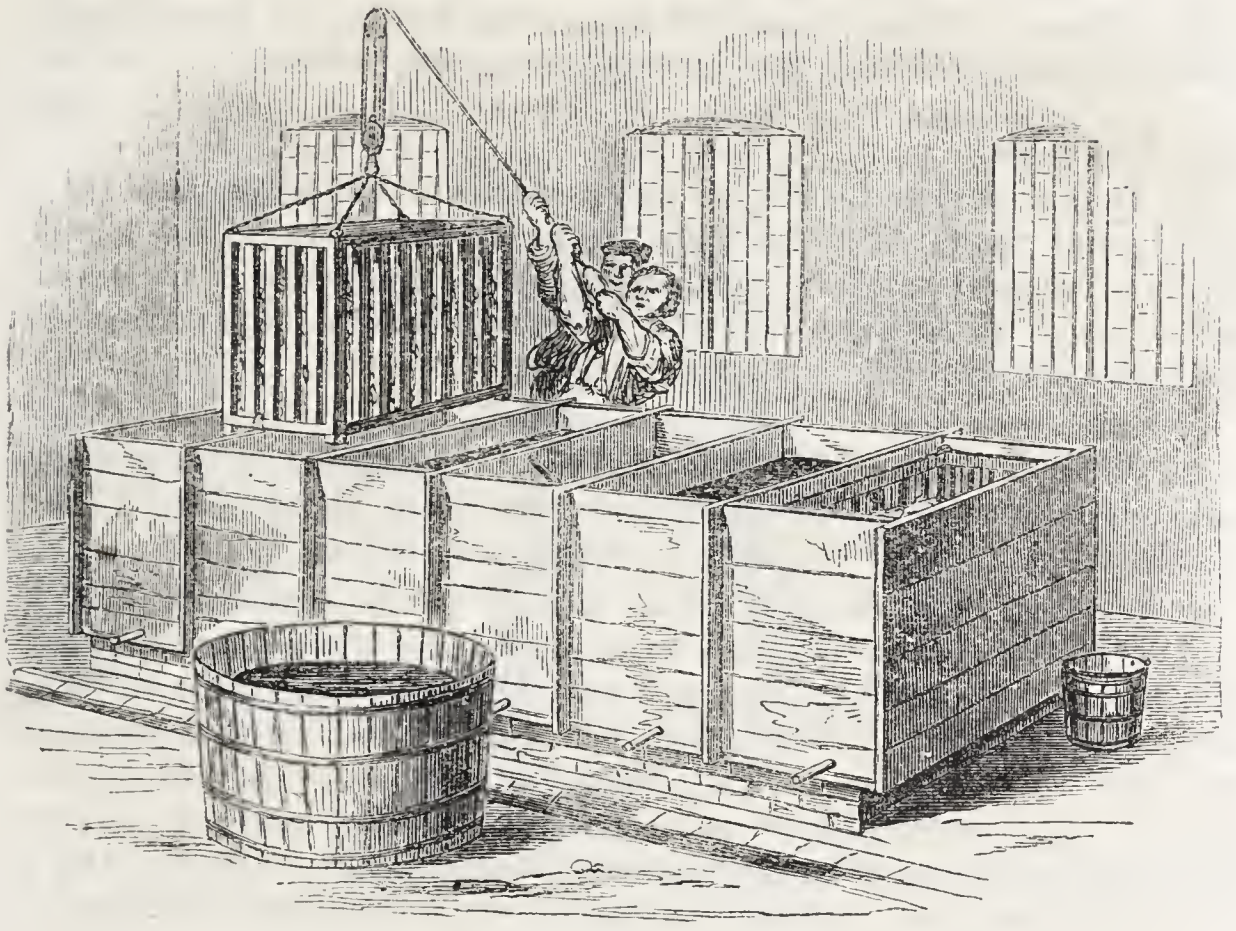
The vegetable glue is insoluble in water, but when steeped in that liquid, or exposed to moisture, it soon begins to ferment, or undergo a sort of slow putrefaction. When this is completed, the stems are dried, and the fibres separated from the brittle wood by beating, or "breaking."

Q. What is the OPERATION of freeing the flax fibre from the glue which binds it to the wood called?

A. Retting, or *rotting.* That which has been steeped in water is called *water-rotted flax* and hemp; that which has been exposed to the air and moisture is called *dew-rotted.*

The Chevalier Claussen's process of preparing flax has excited considerable attention; it is conducted in the following manner:—The flax being gathered when the seeds are ripe, it is *rippled;* that is to say, it is drawn by handfuls through an iron comb, which effectually separates the bolls, or seed-heads, from the stalks. It is then submitted to a *breaker*, which divests the flax of all the refuse, which refuse is applicable as food for cattle, as well as for manure. Brought from the breaker, it is boiled for four hours in hot caustic soda, or steeped in a cold solution of it for twenty-four hours. It is next washed in a weak solution of sulphuric acid, and then in pure water.

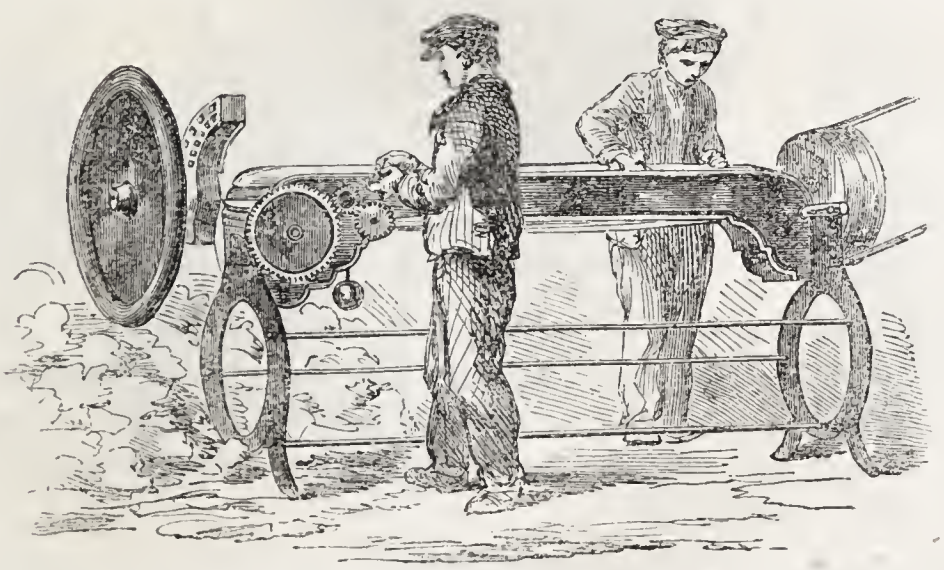
Fig. 159.



VATS FOR STEEPING THE FLAX.

In the engraving is represented the vats employed in the chemical process by M. Claussen. It shows the arrangement of the six vats, with the cradles in which the fibres are placed. One is being hoisted out, to be removed to the next vat. The first vat contains a solution of carbonate of soda; the second, a weak solution of sulphuric acid; the third, another vat of soda; the fourth, bleaching water—a solution of chloride of lime and sulphate of magnesia; the fifth, diluted sulphuric acid; sixth, pure water. The fibres, on being withdrawn, are taken to a machine similar to that used in chaff-cutting, when they are cut into lengths adapted for the purposes required.

Fig. 160.



CUTTING FLAX COTTON.

Q. What are the FABRICS manufactured from flax called ?

A. *Linens.* Fabrics made of hemp are similar in properties to those manufactured from flax, except as regards fineness.

Q. Is the manufacture of flax and hemp attended with more DIFFICULTIES than that of cotton, wool, or silk ?

A. It *is.* Owing to the *irregular length* of the *fibres*, and their *rigidity* and *woody character*, there are many difficulties in the way of spinning flax and hemp by machinery; the manufacture of the finest threads used for lace and cambric is, for this reason, still performed by hand upon the ancient spinning-wheel.

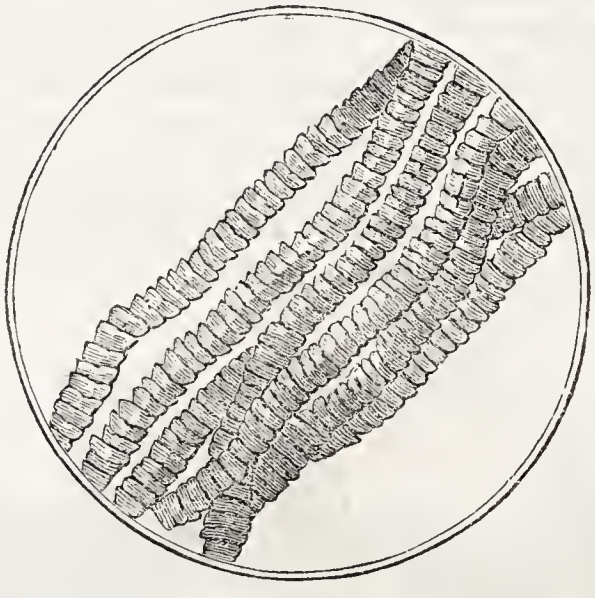
Q. What is WOOL ?

A. Wool is the *peculiar substance* which covers the skins of *sheep* and some other animals, as the *beaver*, the *llama*, the *goats of Thibet* and *Cashmere.* Wool is simply a modification of hair.

Q. What is the APPEARANCE of WOOL when examined under the MICROSCOPE ?

A. The fibres of wool, when examined under the microscope, are seen to possess a *scaly surface*, causing the edge of the fibre to have the appearance of a *fine saw*, with the teeth sloping in the direction from the roots to the points. Were a number of thimbles with uneven edges inserted into each other, a cylinder would result not dissimilar in outline from a filament of merino wool. (*See fig.* 161.) It is to this peculiar structure that wool owes its property of felting.

Fig. 161.



FILAMENTS OF MERINO WOOL.

Q. How does the peculiar ROUGH surface of wool cause it to FELT ?

A. The little imbrications or scales of the fibres lay hold and *match into each other;* so that when a mass of wool is alternately compressed and relaxed, the filaments become enlarged and *compacted* into a solid tissue, which is called *felt.*

Q. Does HAIR also possess FELTING properties ?

A. Some *varieties* of hair, included under the term *fur*, have

roughened surfaces, which causes them to felt. Both hair and wool, when heated or rubbed, have a tendency to curl up. This felting property of wool and fur is taken advantage of in the manufacture of hats.

Fig. 162.

Fig. 162 exhibits the appearance of the hair of the seal (*a*), and of a species of caterpillar (*b*), when viewed under the microscope.

Q. What is SILK?

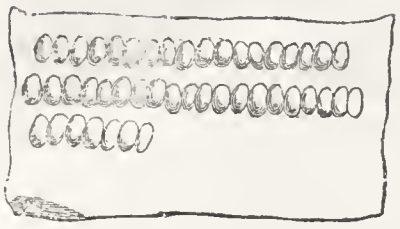
A. Silk is the *secretion of a caterpillar*, the larva of a species of moth, called the silk moth, originally found in China.

The changes which the silk insect undergoes preparatory to producing the silk are as follows:—This insect is subject to four metamorphoses, or changes. It is first of all an egg, produced by a species of moth, which the warmth of spring brings forth in the form of a caterpillar (*a*, fig. 163). This caterpillar, at the end of twenty or thirty days, having attained maturity of size, commences spinning silk fibre, in which it envelopes

Fig. 163.

itself preparatory to changing to its third or chrysalis state (*b*), a sort of mummy condition, in which the enveloped insect lies apparently dead for fifteen or twenty days. At the end of this period it bursts through its shroud, and comes forth a butterfly, or moth (*c*).

Fig. 164.



Q. What is the ENVELOPE in which the worm encases itself called?

A. A *cocoon*. (*See fig.* 164.)

Q. How is the silk OBTAINED from the cocoon?

A. By *unwinding* the fibres which compose it.

The original threads are too fine for manufacturing purposes, and therefore, in unwinding or reeling them off from the cocoons, the ends or threads of several cocoons are joined together in hot water, which softens their natural gummy covering, and causes them to cohere into a single thread.

Q. Of what is the silk COMPOSED?

A. Of a species of *gummy matter* secreted within the body of the worm. By dissecting the worm at the time it commences spinning the silk may be taken out as a separate mass.

Q. What is the APPEARANCE of the silk fibre?

A. The cocoon threads are *twin tubes* laid *parallel* by the worm in the act of spinning, and glued together with more or less uniformity by the varnish which covers their whole surface. Each filament of this thread is about the two thousandth part of an inch in diameter.

CHAPTER LIX.

MANUFACTURE OF TEXTILE FABRICS.

Q. Upon what does the STRENGTH of cordage, and the utility of flexible fibres which serve as clothing, depend?

A. Upon the *friction* or *adhesion* produced by the twisting and intermixture of the fibres.

Q. Is a TWISTED CORD as STRONG as the fibres that compose it, supposing the fibres and cord to be of the same length?

A. It is *not* as strong.

Q. Then what is the OBJECT of TWISTING fibres, as is done in the manufacture of textile fabrics?

A. In order to *connect* successive numbers of fibres in such a manner that, besides the mutual pressure which their own elasticity causes them to exert, any additional force applied in the direction of the length of the aggregate, may tend to bring their parts into closer contact, and augment their adhesion to each other.

Q. What is SPINNING?

A. The *twisting of fibres into a thread or cord.* Care is especially taken in spinning, that the fibres shall be intermixed, and their extremities engaged as much as possible in the centre of the twist, since it is obvious that if any fibre were wholly external to the rest, it could not be retained in the yarn.

Q. In the spinning of a thread of wool, cotton, or flax, what is the FIRST ESSENTIAL OPERATION ?

A. That of *straightening the fibres*, and laying them uniformly in a parallel direction. This, in the case of cotton and wool, is called carding; in flax and hemp, heckling. In cotton and wool, as the band or sheet of fibres comes from the cards, it is drawn by rollers through a hollow cone, or trumpet mouth, which contracts it into a narrow ribbon, which is called a *sliver*. The slivers are delivered coiled up in tin cans, ready for the next operation.

Carding is a species of combing. If we were to take two combs, and pass the teeth of the one between those of the other, we should have an idea of the process. Carding is combing out, by means of a great number of wires acting in a contrary direction.

Q. What is the NEXT STEP for forming a thread ?

A. It is the *elongating the slivers* produced from the cards, by drawing out the *ribbon of parallel fibres.* The accomplishment of this by machinery was the great invention of Arkwright, which so wonderfully advanced the manufacture of cotton fabrics. The "sliver," elongated and drawn out, is called a "roving."

Q. How is the DRAWING EFFECTED ?

A. It is performed by means of *two pairs of rollers.* The upper roller of the first pair is covered with leather, which, being an elastic substance, is pressed down by means of a spring or weight. The lower roller, made of metal, is grooved in order to keep a firm hold upon the fibres of the cotton. Another similar pair of rollers is placed near those which have been described. The second pair, moving with a greater velocity, pull out the fibres from the first pair of rollers. If the surface of the last pair move with twice or thrice the velocity of the first pair, the cotton will be drawn twice or thrice finer than it was before.

In pouring any thick fluid in a stream from one vessel to the other, it will be observed that the upper part of the stream is much larger and thicker than the lower part. In like manner, a sheet of water passing over a dam is much thicker at the top than at the bottom of the fall. In both these cases, the accelerated motion gained in falling causes the lower particles of the fluid to move faster than the uppermost ones ; and for this reason the stream or sheet is drawn or thinned out at the base. In a like manner, by causing a ribbon of parallel fibres to pass through rollers revolving with unequal velocities, the fibres are drawn or thinned out at that end of the ribbon moving most rapidly.

Q. What are the SUCCEEDING OPERATIONS ?

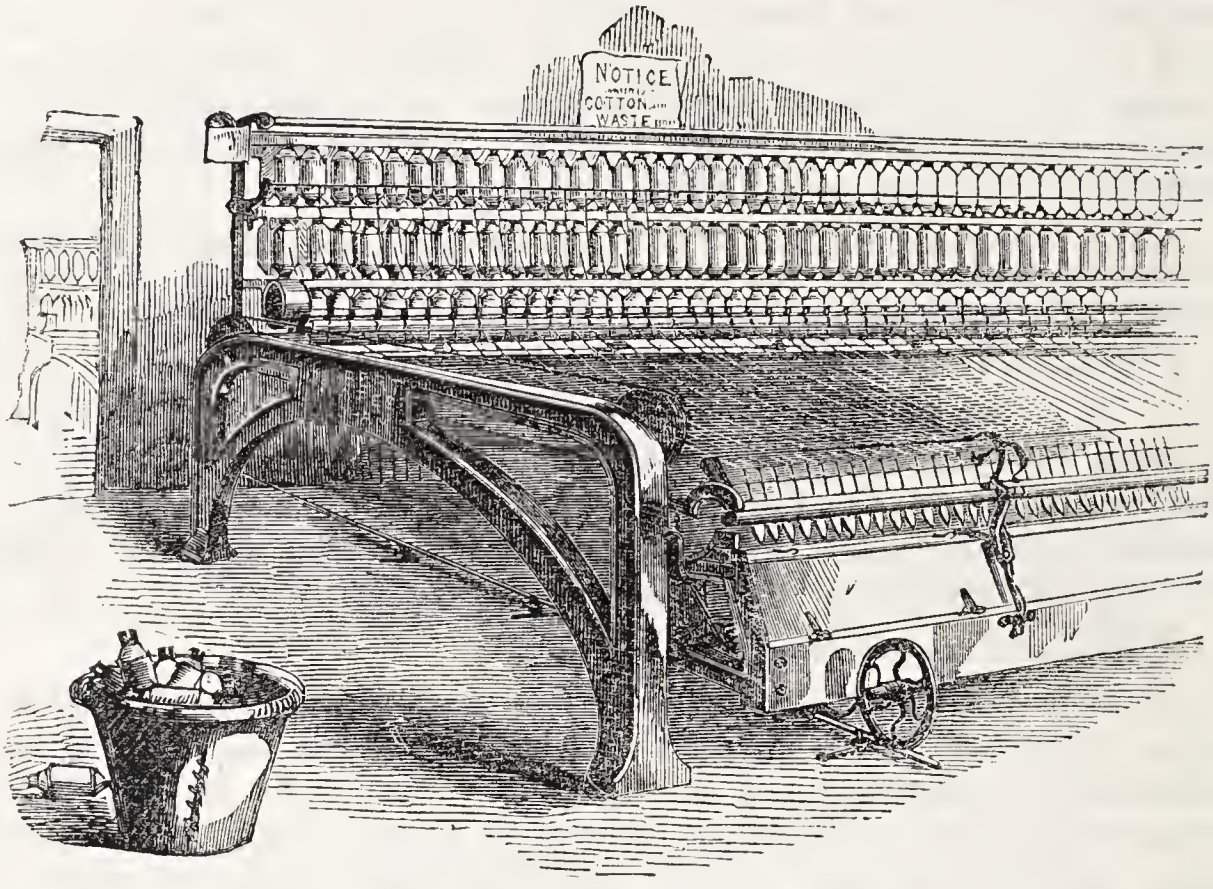
A. The cotton is now *one continuous cord*, or "roving;" but in order to make it serviceable, it is necessary to *twist* it. This is effected in two operations, during which the cotton is farther drawn out by passing through pairs of rollers, and twisted by means of an arrangement called a *flyer;* after which, the thread, wound upon spools, called bobbins, is ready for the process of weaving.

The process of forming wool and flax into thread or yarns is substantially the same as that of cotton-spinning. In silk it is, however, different, as the worm itself spins the thread perfect and continuous.

All the different and beautiful machines which have been invented during the last hundred years for the spinning of cotton are different contrivances for effecting two

objects: the first is the elongating the roving, until it contains in thickness exactly as many fibres as are necessary to produce the required size of yarns; and, second, the twisting of these yarns into a compact thread.

Fig. 165.

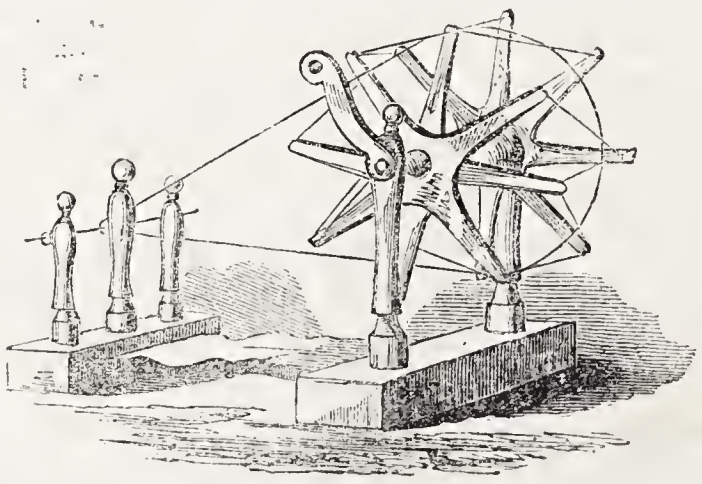


MULE, OR SPINNING JENNY.

Q. What is a SPINNING MULE?

A. It is a *carriage* some twenty or thirty feet long, travelling to and fro, and drawing out the most delicate threads through *hundreds of spindles*, whirling at a rate which scarcely permits the eye to trace their motions.

Fig. 166.



HINDOO SPINNING WHEEL.

Q. Can you give an illustration of the WONDERFUL EFFECT which the introduction of cotton-spinning machinery has had upon the production and cost of yarn and cloth?

A. At the present time, *one man* can attend to a mule containing

one thousand and eighty-eight spindles, each spinning *three hanks*, or *three thousand two hundred and sixty-four hanks* in the aggregate, *per day*. In Hindostan, where they still spin by hand, it would be extravagant to expect a spinner to accomplish one hank per day; so that, in the United Kingdom, we find the same amount of manual labour, by improved machinery, doing more than three thousand times the work.

Q. What is WEAVING?

A. Weaving is the art of *combining threads*, *yarns*, *filaments*, or *strips* of different materials, so as to form a *cloth* or textile fabric.

Q. In weaving, the first step is to form the WARP: what is this?

A. The term warp is applied to the *threads* which form the *length of the cloth*. It consists of parallel threads continued through the whole length of the intended piece, and sufficient in number to constitute its breadth.

Q. What NAME is applied to the THREADS which run TRANSVERSELY across the cloth?

A. They are called the *woof;* sometimes, also, the *weft* and the *filling*. It consists of one unbroken thread, passed alternately over and under each thread of the warp, backwards and forwards. Plain weaving, therefore, is merely the process of making each single thread interlace with that next to it, the threads crossing at right angles.

Fig. 167.

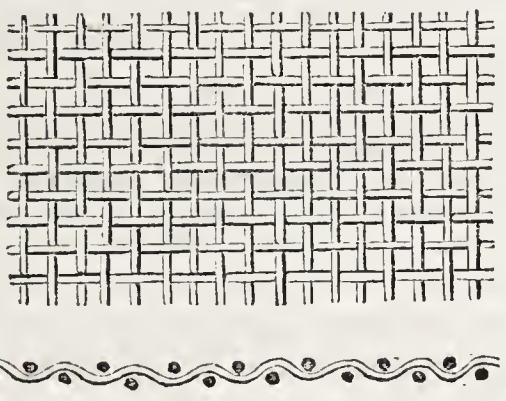


Fig. 167 represents the appearance of a piece of plain cloth seen through a microscope; the alternate intersections of the threads are seen in the lower figure.

Q. What is a SHUTTLE?

A. A shuttle is a *long*, *narrow box*, *pointed at both ends*, containing a ball of thread or yarn; as this is passed through the alternate threads of the warp, the ball within it unwinds, and leaves the thread which constitutes the woof.

Q. How are TWILLED goods woven?

A. In these goods, the threads of the warp and woof do not cross each other *alternately*, but only the *third*, *fourth*, *fifth*, *sixth*, &c., cross each other.

Fig. 168*a*.

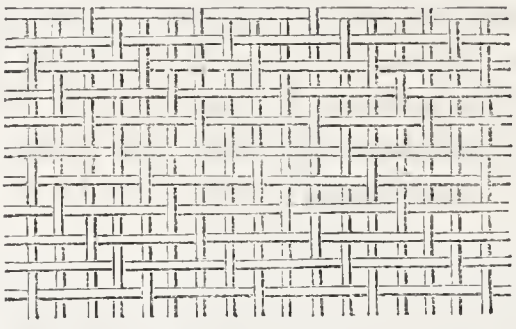


Fig. 168*a* is an enlarged representation of a piece of twilled cloth, by which it will be seen that the same thread of woof is separated from the warp while passing over three threads, and is held down while passing over the fourth.

Q. How are BRUSSELS and WILTON CARPETS woven?

A. In these fabrics the basis is a warp and woof of *strong linen thread;* but to every two threads of linen in the warp there is added a parcel of about *ten threads* of woollen of different colours. The linen thread never appears upon the upper surface, but parts of the woollen threads are from time to time drawn up in *loops*, by being woven over *wires* of the breadth of the cloth.

Fig. 168*b*.

In Brussels carpets these wires are simply drawn out, and the loops left standing; but in Wilton carpets and in velvets they are cut out by passing a sharp knife through the loops. In this way a nap or pile is produced. (See fig. 168*b*.)

Brussels has long ceased to supply us with carpets, and carefully guards against our manufactures by heavy custom duties; otherwise, Kidderminster would supply carpets for Brussels. Rather let us say, the manufacturers of Kidderminster carpets would supply Brussels with carpets, for Kidderminster itself no longer makes the carpet that bears the name of that borough; and we depend on the manufacturers in the north of England and west of Scotland for that production, the Kidderminster carpet-makers having directed their attention to the higher qualities of carpet manufacture.

Q. Upon what does the PROCESS of PAPER-MAKING depend?

A. Upon the *minute division of the fibres of the vegetable substances employed*, and afterwards on their *cohesion.*

Q. How does paper intended for WRITING UPON differ from PRINTING papers?

A. Paper intended for writing upon is *dipped in a thin solution of glue* or *gelatine*, obtained from the shreds and parings of animal skins. This process is termed "*sizing.*"

Q. What is the BENEFIT of sizing paper?

A. It *increases its strength;* and, by filling the interstices between the fibres of the paper, *prevents* the *ink from spreading* among the fibres by capillary attraction.

Q. Why does not PRINTING INK SPREAD upon unsized paper as well as writing ink?

A. Because printing ink is *oily* instead of watery, and has so much consistence, that it is not liable to run and spread.

Q. What is PAPIER-MACHÉ ?

A. The name papier-maché is given to articles produced either by *pressing the pulp of paper between dies* or *moulds*, or by *pasting sheets of paper upon models.* The articles, when dry, are varnished, japanned, and ornamented.

The old method of manufacturing papier-maché is as follows :—The paper for use is gray in colour, but similar in texture to ordinary blotting-paper. Before using it the paper is well saturated with flour and glue, mixed with water, in about equal proportions, and is then laid on the mould of the article intended to be produced. These moulds are of iron, brass, or copper. The mould, coated with the first layer of paper, is then dried for twelve hours. A careful smoothing with a file follows ; after which another deposit of paper is made. The processes of drying and smoothing are successively repeated with each additional layer of paper, until the article assumes the required strength and thickness. When the newly-formed article is taken from the mould, the several parts are planed, filed, and trimmed, so as to be quite correct and level. The process of stoving then follows, after which the varnish is laid on, and brought to a smooth, hard, brilliant surface. The article is then coated with several coatings of shell-lac varnish, coloured, which, after being hardened, are scraped quite level. The fine surface is produced by hand polishing with rotten stone and oil. Many alterations have, however, been made in the process, and the paper is now usually reduced to pulp, and cast into the form required.

CHAPTER LX.

DYEING AND CALICO PRINTING.

Q. In what does the art of DYEING consist ?

A. In *impregnating* cloths and other flexible fabrics *with colouring substances*, in such a manner that the acquired colour may remain permanent under the common exposures to which the stuffs may be liable.

Q. How is this EFFECTED ?

A. By producing a *chemical union* between the *materials* to be dyed and the *colouring matter.*

Q. Do DIFFERENT MATERIALS present DIFFERENT ATTRACTIONS for dye-stuffs, and ABSORB colouring matter in different proportions ?

A. They *do. Wool* appears to have the *greatest* attraction for colouring substances; silk comes next to it—then cotton—and, lastly, hemp and flax.

Q. Into what TWO CLASSES have colouring substances used in dyeing been divided ?

A. Into *adjective* and *substantive colours.*

Q. What is a SUBSTANTIVE colour ?

A. One that *communicates its tint* immediately to the subtances to be dyed, without the *intervention of a third substance.*

Q. What is an ADJECTIVE colour ?

A. One that requires the *intervention of a third substance*, that

possesses a joint attraction for the colouring matter and for the substance to be dyed.

Q. To which class do MOST of the COLOURS used in dyeing BELONG ?

A. To the *adjective* colours; if we except indigo, there is scarcely a dyestuff that imparts directly its own colour to goods; and the greater number of dye-drugs have so weak an affinity for cotton goods especially, that alone they impart no colour sufficiently permanent to deserve the name of a dye.

Q. How, then, does the dyer contrive to impart to COTTON such beautiful colours by using substances which alone impart little or no colouring matter to the cloth ?

A. When the dyer finds there is *no affinity* between the goods and any colouring substance which is put in his possession, he endeavours to find a *third* substance which has a mutual attraction for the cloth and colouring matter; so that by combining the solution with the cloth, and then passing the cloth through the dyeing solution, the dyeing matter combines with the substance which is upon the goods, and constitutes a *dye*.

Q. What is this INTERMEDIATE SUBSTANCE called ?

A. A *mordant*, from the French word *mordre*, "to bite," from an idea which the old dyers had that these substances bit, or opened a passage into the fibres of the cloth, giving access to the colour.

Q. Can you explain practically the manner in which a MORDANT ACTS in dyeing ?

A. A solution of gallic acid is nearly colourless, and a solution of copperas (sulphate of iron) is in the same condition. Cloth, dipped in either of these solutions, will present no immediate change of colour; but if the cloth be *first* soaked in the *solution of iron*, and then passed into the solution of *gallic acid*, the acid and the base will unite, and form a beautiful *black colour* within the texture of the cloth.

Q. Why would a colour so produced be called a FAST COLOUR ?

A. Because the colour is formed by the union of the gallic acid and the iron; and the iron having penetrated into the *interior of the fibres*, the colouring matter is developed there by the soaking in of the acid. Being thus formed in, and incorporated with, the very substance of the cloth, the colour will only *disappear* when the texture and fibre of the cloth is *destroyed*.

Q. How has the use of MORDANTS added greatly to the RESOURCES of the dyer ?

A. Because a *single colouring substance* will impart very *different colours* with *different mordants;* thus an extract of logwood will dye, with iron, black; with a solution of tin, violet; and by using other different mordants, this one vegetable extract will give all the shades of colour from a yellowish-white to a violet; from a lavender to a purple; and from a slate-brown to a black.

Q. What is the PROCESS of CALICO PRINTING ?

A. The cloth is prepared by *bleaching* and other processes, which dispose it to receive the colour. The figures are then *stamped* or

printed upon it from *plates* or *rollers*, which have been previously covered with different mordants, in the same way that ink is applied to types. The cloth is then passed through the solution of dye, and those parts which have been printed with the mordant seize upon and retain the colour. The cloth is afterwards washed, when all the colour *not combined* with the mordant *disappears*.

CHAPTER LXI.

PRINTING, ENGRAVING, AND LITHOGRAPHY.

Q. What is PRINTING?

A. The word printing is commonly applied to the art of *taking impressions of letters* or *type*, *with ink*, *upon paper*.

Q. Who was the INVENTOR of printing?

A. The honour of the invention is disputed. Some bestow it on *John Faust*, others on *John Guttenburg*, others on *Peter Schoeffer*. All of them practised the art about the same time. The last-named invented *metal types* in 1452.

Q. How was printing effected before the invention of METAL TYPES?

A. The *letters* and *words* were *cut on blocks of wood*, as is still the case in China, and impressions were taken from the block.

Q. Which was the FIRST BOOK ever printed in England?

A. *Caxton's* "Game and Playe of Chesse." It was printed in 1474. Caxton's printing office was a ruined chapel in Westminster Abbey.

Q. What book was first printed in the ENGLISH language?

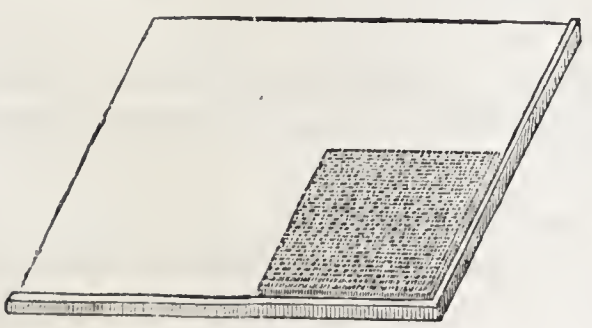
A. The "Recollections of the History of Troy." Caxton translated it from the French; and he tells us in the preface, that he "had practised and learned at great charge and dispense to ordain the said book in print."

Q. What is the COMMON PROCESS of printing?

A. What is properly called printing consists but of *one process*—namely, *taking impressions on paper from the types* or *woodcuts;* but we commonly apply the phrase to the *whole* art—that is, to the setting up or arranging the type as well as that of taking the impression.

The letters, or types, are first arranged in a box, or *case*, every letter in its own alphabetical compartment. The compositor, in setting up lines of type, places the letters in a small frame, called a *composing stick*, which he holds in his hand, until, letter by letter, and word by word, the composing stick is filled. He then transfers the matter thus set up to a *galley*. (*See fig.* 169.) After this the types are made up into pages, which are arranged in a strong iron frame, called a *chase*, pieces of wood, or metal (called *furniture*), being placed between the pages, to keep them apart at proper distances. The whole is then fastened or

Fig. 169.

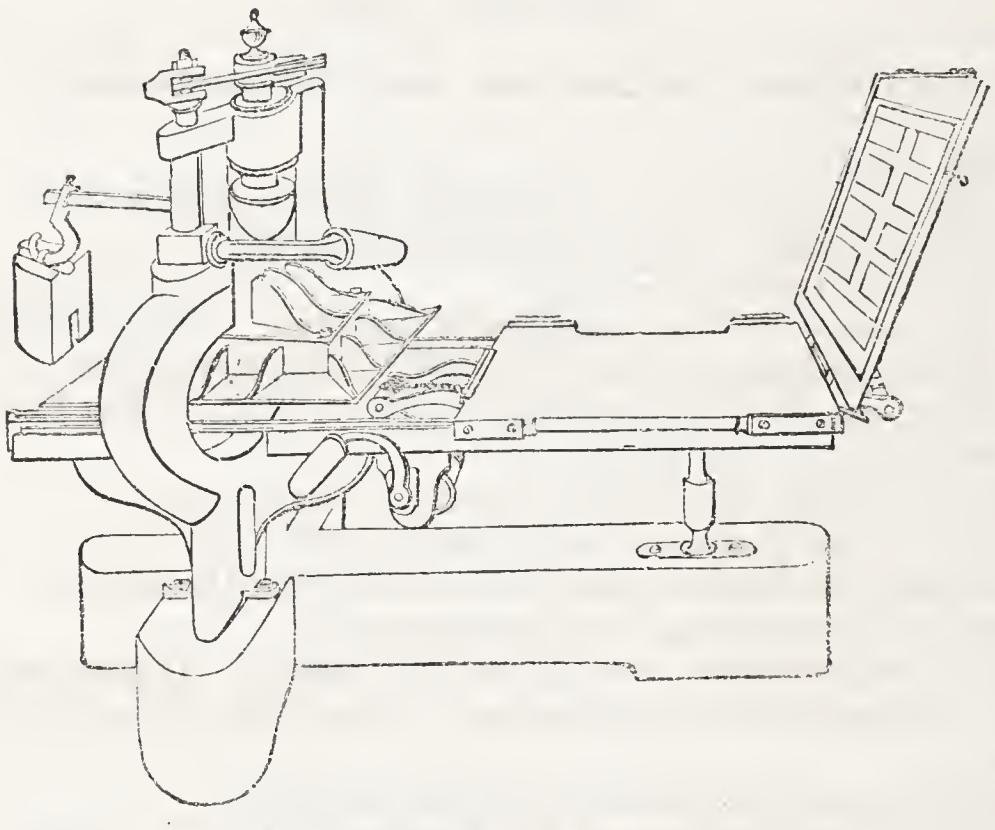


locked up, by means of small wooden wedges; and this when completed is called a form, which, after proper correction and revision, is ready for the pressman to take impressions from.

Q. What is the PRINTING PRESS?

A. The machine by which the *impressions are taken.* These are of *various kinds.* Formerly, they were all *worked by hand;* mechanical appliances were afterwards employed; and steam-power is now applied to that purpose. The engraving below represents a Stanhope hand press.

Fig. 170.



The following is a brief review of the progress of printing machinery. The first patent was obtained by Nicholson, in 1790, who then proposed placing both the types and paper upon cylinders, and distributing and applying the ink also by cylinders. In 1813, Messrs. Donken and Bacon introduced composition rollers. In 1814, Kœnig made the first working printing machine, and erected two of them at the *Times* office, each of which produced 1,800 impressions per hour. In 1816, Mr. Cowper made a machine to print from curved stereotyped plates; and, in 1818, one to print books and newspapers from ordinary type, which machines are now in general use. In these machines he introduced the system of printing now so common. These machines printed from 2,000 to 2,400 impressions per hour. The demand for greater speed continuing, Messrs. Cowper and Applegarth, in 1827, conjointly invented the four-cylinder machine, which printed from 4,000 to 5,000 impressions per hour. The last, and most important, improvement was made in 1848; and the visitors to the Industrial Exhibition of 1851 had full opportunity of inspecting the apparatus.

Q. Is there MORE than ONE KIND of printing?

A. Yes; there are several methods. Sometimes *movable letters* are employed, sometimes *solid pages*, casts of the movable letters, called stereotype, are used.

Q. At what time was the STEREOTYPE PROCESS first introduced?

A. The present mode of stereotype was invented by *Mr. Tilloch*, in 1779.

Q. How does common ENGRAVING differ from PRINTING?

A. Common engraving differs from printing in having its subjects or devices cut *into* or *below* the surface of a metallic plate, instead of being *elevated* or *raised above it*, as in types or woodcuts.

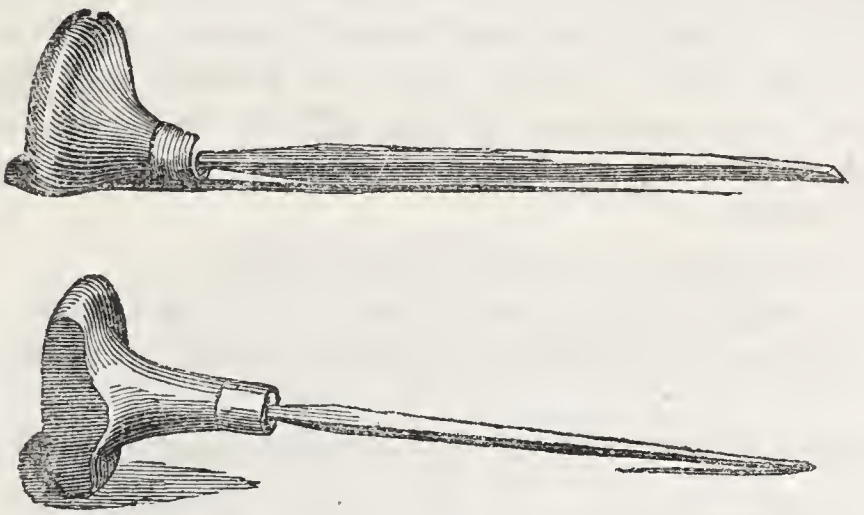
Q. What are the principal VARIETIES or styles of engraving on copper or metal?

A. 1, *Line engraving;* 2, *stippling;* 3, *etching;* 4, *mezzotint;* 5, *aquatint.*

Q. What is LINE ENGRAVING?

A. In this species of engraving, the surfaces and figures, the lights and shades, are produced by a *multitude of minute lines* cut into the metal, and approaching each other so nearly, that the inequality produced by the admixture of black and white lines does not offend the eye, nor interrupt the harmony of the piece.

Fig. 171.



GRAVERS.

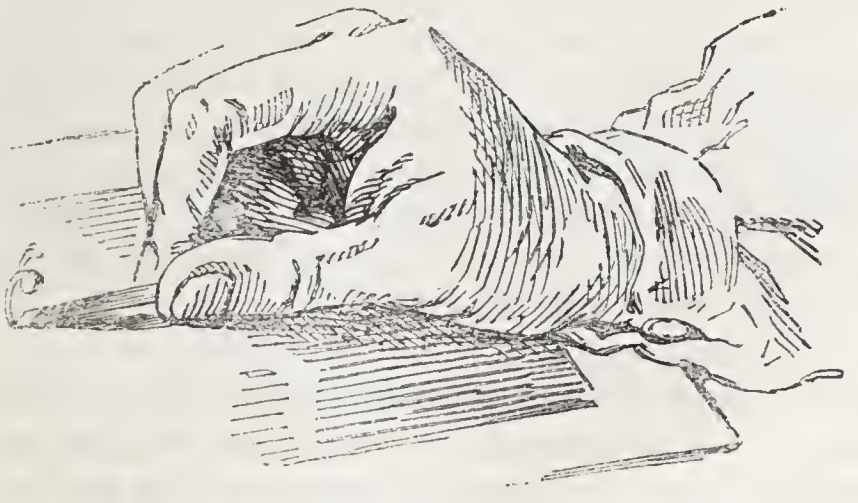
Q. By WHAT MEANS are these lines cut into the plate?

A. With a tool called a *graver.*

Q. What is a GRAVER?

A. The tool called a graver differs in size and shape according to the character of the *line* which it is intended to produce.

Fig. 172.



WAY IN WHICH A LINE IS TRACED BY THE GRAVER.

In making the incision, the graver is pushed forward in the direction of the line required, being held by the handle at an angle very slightly inclined to the plane of the copper. It is requisite that the graver be well tempered, and great address is necessary in whetting it for use. The angle at the meeting of the two lower sides of the graver forms what is called its belly, and the breadth of the end is called its face. The two sides which form the belly are to be laid flat upon the oil-stone, and rubbed firmly until the belly slightly rises, so that if it were laid flat upon the copper the light could be seen underneath the point; otherwise it would be impossible to use it with freedom, as it would dig unequally deep into the copper. The face is next to be whetted, which is done merely by laying the face of the graver flat upon the stone, with the belly upward, and rubbing it steadily upon a moderate slope until it acquires a very sharp point, taking care that the stone be properly supplied with oil all the while. The gravers sold in the shops are commonly too hard for use, which is known by the frequent breaking of their points; when this is the case, they should be tempered by holding them on a red-hot poker, at a distance of half an inch from the point, until they acquire a faint straw colour; they should then be put into oil to cool; or they may be tempered with a candle, and cooled in the tallow. But it is best not to be hasty in tempering; for if the graver is only a little too hard, whetting alone will frequently bring it into good condition.

Q. How are GRADATIONS in LIGHT and SHADE effected in line engraving?

A. By the *gradual* and *simultaneous tapering of all the lines* which constitute the dark portions; and the softness and regularity with which this is accomplished greatly affects the beauty of the piecen Very dark shades are produced by lines crossing each other either i. squares or curves.

Q. What is that method of engraving called STIPPLING?

A. It resembles line engraving in its processes, except that, instead of *lines*, it is finished by *minute points* or excavations in the copper.

The variations and progressive magnitude of these dots give the whole effect to stippled engraving.

Q. What is ETCHING?

A. In etching, the metal plate is covered with a *varnish* of wax, resin, &c. The picture is drawn upon this coating with a needle, care being taken that the lines penetrate to the metal. *Etching-points* or *needles* are nearly similar in appearance to sewing-needles, but fixed into handles four or five inches long; some are made of an oval form, to produce broader lines with. *Dry point* is, in fact, nothing more than the common etching-needle brought to a very fine point. It is used to cut or scratch the more delicate lines with, such as skies, &c. &c. It does not, like the graver, cut the copper clean out, but throws it up on each side of the line produced by its progress through the metal: this is called the burr, which is removed by a scraper. This burr was left on by Rembrandt, until it wore away in the progress of printing, which it soon does; but by his management it added greatly to the effect of the etching, and impressions from his works with the burr on are much valued.

Q. What is the NEXT process?

A. *Acid* is then poured upon the plate, when a chemical action takes place in all the lines or points where the copper is denuded by the strokes of the needle, while the rest of the surface is protected by the varnish. The picture is thus eaten or etched out of the metal

by the action of the acid. Etched engravings never possess the smoothness and finish of mechanical work.

Q. What is MEZZOTINT?

A. In mezzotint the whole surface of the copper plate is *first roughened*, or covered with *minute prominences* and excavations, too small to be obvious to the naked eye; so that, if an impression be taken from it in this state, it has a *uniform*, *velvety*, *black appearance*. The picture is then produced by pressing down or rubbing out the roughness of the plate to the extent of the intended figure, obliterating the ground for lights, and leaving it for shades. Care is taken to preserve the insensible gradations of light and shade, upon which the harmony of the piece depends.

Q. What is AQUATINT?

A. This is done by a method partially mechanical, partially chemical. It consists in producing *chemically a rough ground*, covering the surface of the figure to be engraved, and afterwards introducing the *lights* and *shades* by *mechanical* means.

Fig. 173.

INKING THE PLATE.

Q. In what MANNER is COPPERPLATE PRINTING effected?

A. The *cavities* of the engraving are thoroughly *charged with ink*, and the smooth surface of the plate *wiped as clean as possible*. The latter part of the wiping is always performed by the *palm of the hand*. The ink, therefore, remains only in crevices of the engraving into which the hand does not penetrate in wiping the surface. The paper is then strongly pressed upon the plate, and portions of it are forced down into all the cavities of the engraving. The ink, or a portion of it, leaves the copper and adheres to the paper, giving an exact representation of the whole engraving.

Q. Upon what does the process of STEEL ENGRAVING DEPEND?

A. On the quality, which steel possesses, of being softened by losing a part of its carbon, and afterwards of being hardened by regaining it. The engraving is first made upon *soft steel*, and the plate is then *hardened*.

Q. What is the GREAT-ADVANTAGE of steel plates in engraving?

A. On account of their *hardness*, they last for an *indefinite time*, and yield an almost unlimited number of impressions; whereas a copperplate wears out after two or three thousand impressions, and even much sooner, if the engraving be fine.

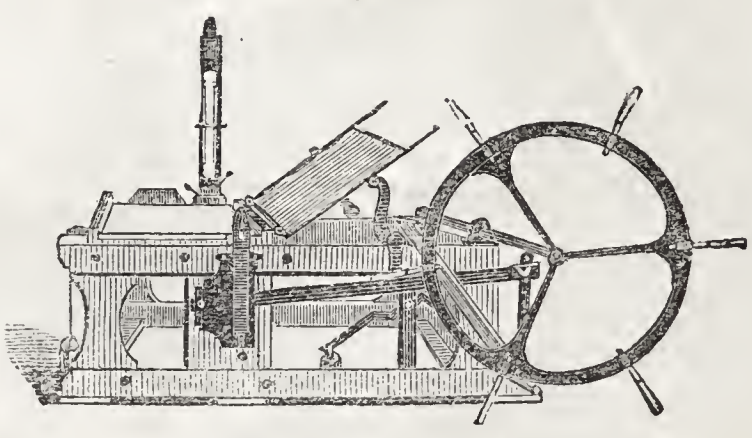
Q. What is LITHOGRAPHY?

A. The art of taking impressions from drawings or writings made on a peculiar smooth *stone surface*, *without engraving*.

Q. What sort of STONES are used for LITHOGRAPHIC printing?

A. Lithography owes not only its existence, but its possibility, to the fact, that several quarries in *Bavaria*, Germany, furnish a peculiar species of *limestone*, uniform in texture, apparently compact, yet having a somewhat open grain. A grained or smooth surface of this stone, therefore, having a porous structure, absorbs and firmly retains both water and oil, or inks made with oils or fats.

Fig. 174.



A LITHOGRAPHIC PRESS.

Q. What is the THEORY of LITHOGRAPHIC printing?

A. If parts of the stone surface are *covered* with a *drawing* in *oil* or *fat*, the remaining surface may be *wetted without wetting the inked parts;* and then if ink be rolled over the stone, it will be turned from

the wet parts, and will adhere on the inked parts. Thus any drawing made with an oily ink on the stone, can have its lines duly charged with ink for printing, while all the rest of the stone continues clear.

Impression after impression upon paper can thus be taken off by wetting and inking the stone after each printing. In this process the stone is merely the solid support for the ink and water to adhere to, and the whole manipulation has for its object to ink the ink lines, and them only. If the stone be used when too dry, the whole surface takes the ink and prints, thus totally ruining the drawing.

Q. What is the so-called TRANSFER PRINTING by the lithographic process?

A. The term transfer is applied to a stone on whose face the ink from an original drawing or writing, or from an impression on paper, has been *so thrown down as to admit of printing in the same* manner as if the drawing was first made on stone—thus reproducing the original indefinitely.

Q. What is PRINTING INK composed of?

A. Of *oil*, *varnish*, and *fine lampblack.*

AGRICULTURE AND RURAL ECONOMY.

CHAPTER LXII.

ELEMENTARY PRINCIPLES PERTAINING TO AGRICULTURE.

Q. What is GARDENING?

A. Gardening is the art of *cultivating flowers*, *fruits*, and *vegetables.*

Q. Is this art called by any OTHER and LESS SIMPLE name?

A. Gardening is also called *horticulture*, a word derived from the Latin, meaning garden culture.

Q. Is it an art EASILY and QUICKLY acquired?

A. The degree of skill necessary for raising common vegetables may be acquired without difficulty or long practice; but for the complete knowledge of the art, in its numerous branches, *much experience*, *a good education*, and *some taste* are requisite.

Q. What is the BEST SOIL for a garden?

A. The best soil for a garden is a *rich* and *deep loam.*

Q. What do you mean by LOAM?

A. By loam is meant a *mellow*, *fertile soil*, not stiff and greasy like clay, nor very loose and open like gravel and sand, but having these earths in proper proportions.

Q. What is VEGETABLE MOULD?

A. Vegetable mould is the *dark-coloured soil* we see in old, con-

stantly-manured gardens. Vegetable or animal substances, rotted into earth, become vegetable mould, which contains rich nourishment for plants.

Q. Is it important to have a good SUBSOIL?

A. A good subsoil *is very important.* A very hard clay below, or gravel, if near the surface, are very bad subsoils, though in different respects.

Q. WHY are they bad subsoils?

A. A hard clay bottom will not allow the rain which falls to *pass through it;* therefore, the upper soil is in a state of mud during the winter, and in spring and summer it hardens and cracks.

Q. What is the effect of TOO OPEN a subsoil, such as sand or gravel?

A. If a too open subsoil be near the surface, rain *passes downwards too rapidly.*

Q. What do you think of a soil resting on ROCK?

A. A soil resting on rock is generally *shallow*, *poor*, and *quickly dried up.*

Q. What kind of subsoil is best?

A. The best kind of subsoil is a *sandy* or *calcareous* one, that will allow moisture to pass with moderate rapidity through it; such a subsoil, having no bad qualities in it, will nourish the roots of plants that strike deeply, instead of stopping or destroying their growth

Q. What is the BEST SITUATION for a garden?

A. The best situation for a garden is one *facing the south*, but slightly inclining towards the *east*, to receive the benefit of the morning sun; with perfect shelter from the north, and not exposed to winds that blow harshly and frequently.

Q. How should garden WALKS be LAID OUT and made?

A. First, with a *line*, mark out the *width* of the walk or path; then *dig* the *mould* out of this space and spread it over the borders or beds, and cover the hollow with stones, brick-bats, or dry rubbish, on the top of which a *thick coat of gravel* should be spread. If the subsoil be perfectly dry, no dry rubbish will be necessary.

Q. If the soil contains too much clay, sand, or gravel, can the PROPORTIONS of those earths be LESSENED?

A. Yes; a clay soil can be rendered *less clayey* (after deep draining in the first instance) by mixing with it sand, gravel, road-scrapings, ashes, building rubbish, or any other substances that help to separate the particles of clay. A sandy or gravelly soil may be made *more solid* by mixing with it a good deal of clay.

Q. Is it possible to reduce SPONGY PEAT into garden soil?

A. Yes; the most spongy peat may be reduced to a solid and fertile soil by *being mixed with other earths* and with manure.

SECTION I.—MANURES.

Q. What are MANURES?

A. Manures are the substances employed for *feeding* and *stimulating plants*, and for exciting or altering the qualities of the soil by their union with it.

Q. Mention the GENERAL HEADS under which manures may be classed.

A. Manures may be divided into *three classes:* 1, *animal and vegetable* manures; 2, *mineral* manures; 3, *mixed* manures.

Q. What are the most common ANIMAL and VEGETABLE manures?

A. Farm-yard manure, the manure of poultry, crushed or burned bones, guano, sea-weed, &c.

Q. Are the excrements of ALL animals equally powerful as manures?

A. The excrements of animals fed on *flesh* are *more powerful* than those of animals fed on *vegetables* alone; the excrements of animals fed on oily substances, such us oil-cake, are much more powerful than those of animals fed on straw alone. Even the manure of cattle fed on turnips and grain is far better than that of straw-fed cattle.

The manure of fat animals is of more power than that of lean ones. The manure of the pig, which consumes animal food, is preferable to that of the cow, which feeds on vegetables only; and the manure of the sea-fowl, which feed on fish, is more powerful than that of domestic fowl, fed on grain.

Q. Generally speaking, what is the most ADVANTAGEOUS METHOD of applying the manure of stables, cow-houses, &c.?

A. The best mode of using stable manure, &c., is in *compost.*

Q. What do you mean by a manure COMPOST?

A. By a manure compost is meant a *mixture of fermented litter* from cow-houses, &c., with *mould*, *sods*, *peat*, or any animal or vegetable substances.

Q. What are the NAMES of the chief mineral manures?

A. *Lime*, *gypsum*, *marl*, *sea-sand* containing shells, *phosphate of lime*, *common salt* in some cases, &c.

Q. By what DISTINGUISHING NAME are those mineral manures, such as marl and shell sand, which contain portions of lime, called?

A. Mineral manures which contain lime in any form are called *calcareous*, which word signifies containing lime.

Q. Do mineral manures ENRICH the soil?

A. Mineral manures can hardly be said to enrich the soil, but, by altering its defective qualities, and by preparing substances within it to feed plants, they are *highly serviceable.* Quicklime, in particular, acts powerfully on soil, by dissolving tough vegetable matter, such as peat, and by separating the particles of stiff clay.

Q. How do mineral manures act upon the SOIL?

A. The mineral manures *loosen a stiff soil*, improve its texture, and quicken its sluggish powers

Q. Do not the mineral manures, in some degree, FEED plants?

A. The mineral manures, especially lime, *enter into the substance* of certain classes of plants. For instance, lime is found in the grains of wheat, yet it can hardly be said to nourish the growing wheat any more than the particles of lime which a laying hen picks up can nourish her, though it is necessary to her in forming the egg-shell. Yeast is requisite to make dough ferment, yet, though it assists in making good bread, it does not make it more nourishing.

Q. What is generally understood by the word LIME?

A. By lime, farmers mean *limestone* or *chalk burnt in a kiln;* and quicklime means burnt lime before it has lost its caustic or burning power by exposure to the air or moisture.

Q. Is quicklime a GOOD INGREDIENT in a compost with manure?

A. Quicklime should *never be mixed with manure;* but marl, which contains lime in a very mild form, may be mixed with manure and earthy matter.

Q. Is quicklime USEFUL for any kind of compost?

A. Quicklime may be mixed with the *surface sods of a peat bog*, or any coarse vegetable and earthy matter, which it reduces by its caustic quality into fertilising mould.

Q. Will the EFFECTS of lime LAST LONG?

A. The effects of lime will continue for *six or seven years.*

Q. Which is the LEAST VALUABLE of all the mineral manures?

A. *Gypsum*, or "*plaster of Paris*," as it is called, is the least valuable of the mineral manures for crops in general; but for top-dressing plants of the clover tribe it is very useful, though it is doubtful whether it improves the soil.

Q. How should quicklime be APPLIED to ground in a fallow state?

A. Quicklime should be first reduced to a *powdery state* by slaking it with water, and then scattered over the ground, which ought to be in a perfectly dry condition, else the lime will form lumps of mortar, instead of being blended with the soil. It should be lightly raked or harrowed into the surface.

Q. Ought ANIMAL MANURE to be applied at the same time with LIME?

A. Animal manure should not be put on the ground for *some weeks* after the lime has been spread, because the lime would destroy the best qualities of the manure; and there are few cases in which it would be expedient to use lime in the same season on the same land.

SECTION II.—GROWTH OF PLANTS.

Q. What is the SEED of a plant?

A. The seed of a plant is a *living particle* separating from it, and capable of growing into a new plant of the same kind.

Q. What makes a seed GROW?

A. *Moisture*, *heat*, and a *free supply of air* cause a seed to swell, burst, and push forth a root into the earth and a stem into the air.

Q. What MORE is necessary to make a seed thus break forth into life?

A. In general, it is necessary that a seed should be *covered by earth*, or at least *shaded from light*, because light prevents a seed from undergoing a certain inward change which is necessary to make it start forth into life.

Q. What PART does a seed first put forth?

A. The part that first sprouts from a seed is the *radicle;* which soon becomes an active root, furnished with white threads called spongioles, which act as mouths to plants, by absorbing moisture and carrying it to the plant. The uses of the root are twofold: first, it enables the plant to take fast hold of the ground; secondly, it is also the means of carrying nourishment or food to the plant.

Fig. 175.

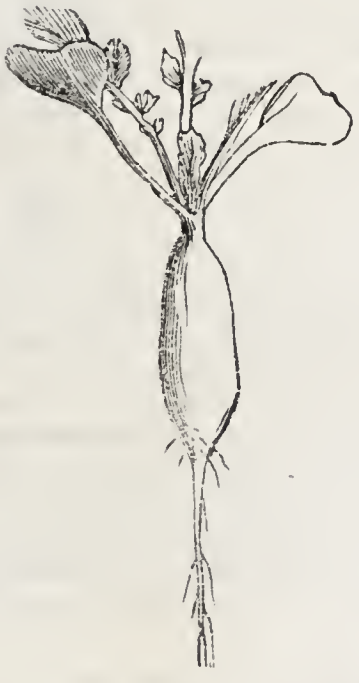


Fig. 176.

In the above engravings we have representations of various species of root. Fig. 175 shows the radish, as a specimen of the spindle-shaped root; fig. 176 the fibrous root, as seen in the pasture grass.

In nearly all cases the end of the stem and the beginning of the root is most distinctly marked; the root seeks the ground, the stem seeks the air. But it occasionally happens that stems become roots, and roots become stems. The Banian tree, for instance, shoots down its stems till they reach the ground, and there take root, forming a great natural arbour, or temple, in which hundreds of people may assemble.

Fig. 177.

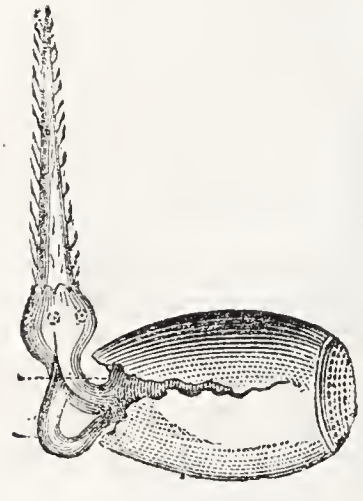
Fig. 178.

Fig. 177 shows the knotty root, the dropwort ; fig. 178 is a tuberous root, as seen in the dahlia.

Q. What is the SECOND part which a seed puts forth ?

A. The second part which issues from the seed is called the *plumule*, which gradually lengthens into a stem furnished with leaves.

Fig. 179.



GERMINATION OF THE ACORN.

The structure of the stems of vegetables is a very important point, and assists the botanist in separating flowering plants into two great divisions. "The acorn, on being planted in the ground, sends down its root and sends up its stem. At first this stem is a little tiny thing ; year by year, however, it grows, until it at length becomes a large tree. If we now cut this tree across, and examine the structure of its section, or cut part, we shall find the appearance to be as follows :—In the first place, commencing our examination from without, we shall find the bark (cortex) separable into two distinct layers, the outer of which is termed *cuticle*, and the inner one *liber*. Passing onwards, we observe the woody fibre, and its central pith. The woody fibre is apparently of two kinds ; the outside softer, and termed *alburnum;* the inside harder, and termed by botanists *duramen*. Lastly, in the centre, comes the pith, or *medulla*. Regarding this section a little more attentively, we shall observe passing from the pith to the bark, and establishing a connection between the two, a series of rays, called medullary rays." Now, all these characters are found in the stem. They point out to us the true nature of the tree, and enable us to classify it correctly. A plant such as the oak is called an exogenous plant ; the other great class are called endogenous. The meaning of these terms has been already explained. What we have to remember is, that these characteristics are ascertained by the stem.

Q. While this infant growth is advancing, and before the roots are able to take up food, how is the young plant NOURISHED ?

A. The starch-like substance within the seed is changed into a species of gum and sugar, and is conveyed to the *radicle* and *plumule* by means of one or two *seed-leaves* called cotyledons, which act as nurses to the new-born plant until it can take its food without their help.

Q. What finally BECOMES of the SEED-LEAVES?

A. When the true leaves shoot out from the stems, the seed-leaves *perish.*

Q. Of what do the TRUE LEAVES consist?

A. They consist of *thin, flattened pieces of vegetable skin,* enclosing a vascular or cellular tissue.

Q. What do you mean by VASCULAR TISSUE?

A. By vascular tissue is meant those little *pipes* or *tubes* which run through vegetables, just like veins and arteries through animal bodies, and which serve to carry juices from one part of the plant to another.

Fig. 180.

Fig. 181.

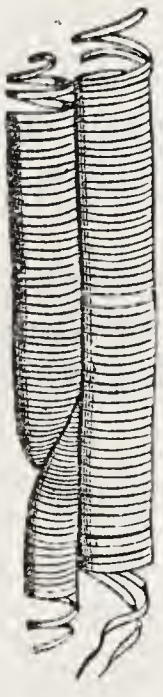


Fig. 182.

The forms of some of these vessels are seen in the above diagram. Fig. 180 represents the dotted vessel of the clematis; fig. 181 the spiral vessels of the melon; fig. 182 the lactiferous, or juice-bearing vessels of the celandine. All these are magnified representations.

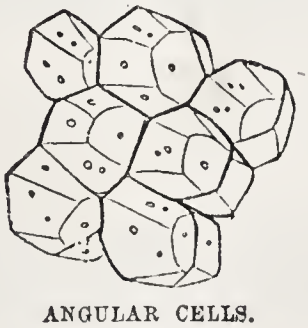
Q. What is meant by CELLULAR TISSUE?

A. By cellular tissue is meant an *assemblage of little cells.* Their proper or natural form is *oval,* but this is often changed by their pressing against each other.

Fig. 183.

OVOID CELLS.

Fig. 184.



ANGULAR CELLS.

Fig. 185.

STAR-FORM CELLS.

Q. What occasions the GREEN COLOUR of leaves?

A. The presence of a colouring matter called *chlorophyl*, from two Greek words, meaning yellowish-green and leaf. By a chemical change, this colouring matter turns to a *red hue* in autumn.

Q. What are the USES of leaves?

A. The uses of leaves are various; the principal use is that by which they act towards the plant as the lungs do for animals, and they may thus be considered the *breathing apparatus* of plants.

Q. What VARIETIES are there in leaves?

A. They vary in form, in the manner in which they are joined to the stem, in *softness*, *hardness*, *thickness*, *thinness*, and in many other ways.

Q. What are meant by the NERVES, or VEINS, of plants?

A. *Nerves* and *veins* in botany mean the same thing, and the terms are applied to those cord-like ribs which run under the surface of leaves.

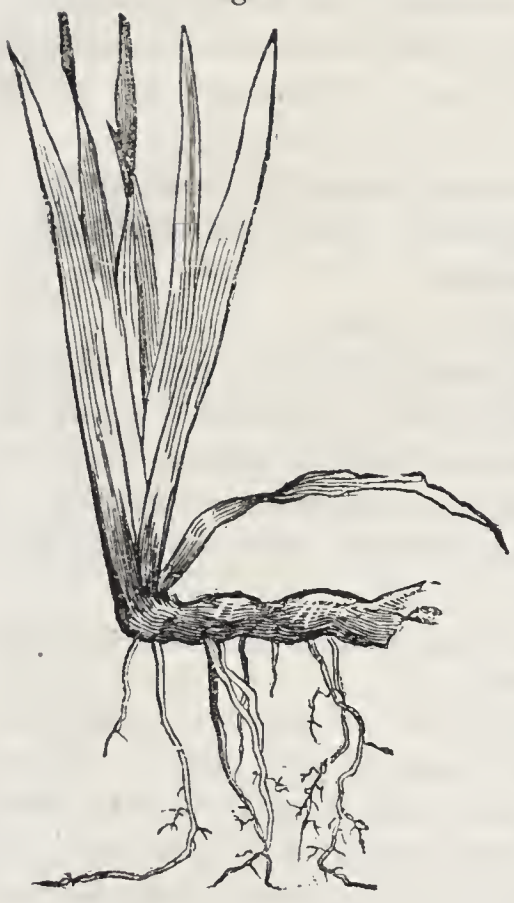
Q. Are the nerves, or veins, of plants ALIKE in ALL leaves?

A. *No;* there are two great divisions, namely, those whose veins form a *kind of network*, and those whose veins *run in straight lines* without intersecting each other.

Fig. 186.

In the above engraving we have a representation of the melon leaf, which affords an excellent specimen of the net-work (reticulated) leaf; or those leaves in which the nerves and veins cross each other, and seem to spread over the leaf in every direction.

Fig. 187.



In the iris leaves we have an illustration of the other variety, namely, the straight-veined leaf. (*See fig.* 187.)

Q. Is there any GENERAL RULE as to the depth of covering necessary for seeds?

A. Experience teaches the gardener better than any rule what depth of covering is most suitable for seeds. A small, tender seed requires the merest *sprinkling of sand or very light loam*, barely enough to shade it and preserve moisture; whereas a bean, which has a very tough covering, will bear a heavy coat of clay, and will force its stem through it, when other seeds could not.

It is plain, that in a sandy soil seeds may be sown deeper than in clay soils; an inch of clay might smother a seed which could bear an inch of sandy loam without injury or inconvenience.

Q. If the covering of seeds be necessary, how is it that so many seeds grow when SELF-SOWN on the surface?

A. Many self-sown seeds, whether acorns or the light seeds of grasses, find sufficient *shading from the light.* An acorn, for instance, becomes buried under a covering of leaves, or falls into some chink in the soil, where it escapes from the light; and small seeds, if they have nothing else to cover them, are shaded for the necessary time by the seeds which lie over and around them.

Q. Is there any reason for supposing that a HEAVY COVERING of seeds gives more depth and fixity to the roots than a light one affords?

A. It is a mistake to suppose that seeds must be well buried in order that the young plants proceeding from them may have a good hold of the ground, because a seed, when it begins to grow, plunges its *roots downwards* and throws its *stem upwards* from the seed; consequently, all the space between the surface of the soil and the seed is occupied by the base of the stem, and not by the roots.

Q. Is FRESHNESS of seed always to be DESIRED?

A. *Old* seed is not generally *to be depended upon;* some seeds, particularly those of an oily quality, fail very soon after ripening; others, if kept in a dry state, retain their growing powers for a length of time.

The kidney-bean has been known to grow after *one hundred years,* and wheat-plants have grown from seed which had been taken from Egyptian mummies, and must have been thousands of years old. The soundness of seeds depends altogether, in many cases, on their having been kept in a dry state; dampness, which makes them grow if properly sown, causes them to rot if not sown.

Q. If the soundness of the seed be doubtful, what is the best way of TESTING it?

A. To test the degree in which seed is sound or otherwise, sow a

certain number in a *pan of earth*. By counting the number of growing ones, the proportion of living to dead seeds can be ascertained, and the quality of seed to be sown calculated. Seeds are not to be rejected merely because they are old.

Q. How are the best seeds to be OBTAINED by persons who save their own seeds?

A. Those persons who save their own seeds should choose the *best plants*, whether fruits, flowers, or vegetables.

Q. In watering seeds and plants, what RULES should be observed?

A. Neither seeds nor plants should be watered except *when the sun has gone down*, because the rays of the sun, acting suddenly upon the moistened plant, injure it; upon moistened ground, where the seeds have not yet appeared, the effect of watering in sunshine would be to draw forth the moisture from the place watered, and make it drier and harder than before.

Q. Why does NATURAL RAIN in summer generally cause plants to GROW more freely and with more vigour than the water from a watering-pot?

A. Rain water generally contains organic substances, ammonia, nitric acid, &c., which invigorate and nourish the plant. When summer rain also is falling, the air becomes moist, and the sun, while its warmth is still acting, does *not counteract*, by his fiery rays, the *good effects* of that moisture, and the soil is then softened and disposed to the entrance of the genial rain.

Q. What KIND of WATER is the best for watering plants, seeds, &c.?

A. The best water for using in the garden is that which contains the *most nourishing substances*, such as that of cesspools and ponds. Rain water also is good. When spring water alone can be obtained, it ought to be exposed some time to the air before it is used.

Q. What is the most CONVENIENT BREADTH of beds for all the close-growing plants, such as onions, and early parsnips, and carrots?

A. The most convenient breadth of beds for onions, parsnips, &c., is *four feet*, with *alleys between them;* this breadth allows a weeder to weed and regularly thin the plants, and to loosen the soil about them, without treading on the beds.

Q. What kind of plants is it most difficult to TRANSPLANT successfully?

A. *Tap-rooted* plants require the greatest care in transplanting; a light soil is most suited to them, and watering should be freely given to their roots.

Q. What is meant by the ROTATION of crops?

A. By rotation of crops is meant a *regular succession of crops*, so that the same kinds shall not follow each other immediately.

Q. Why is a CHANGE of crops to be RECOMMENDED?

A. Since plants of the same sort *consume the same elements* of food contained in the soil, it follows that the continued cultivation of the same plants will, more or less, deprive the soil of the elements on which they feed.

Where frequent and abundant manuring is given, regard to rotations is of no great

importance; but in a garden poorly manured, and where, therefore, the dependencies on the soil itself for the nourishment of the crops, a rotation of them is absolutely necessary.

Q. Are there not, however, many perennial plants which must remain in the SAME GROUND for several years?

A. Such perennial vegetables as asparagus, rhubarb, and artichokes ought not to be displaced within less than *eight or nine years*, or until they begin to fail; but they are manured so amply every year that they do not depend entirely on the soil for their support. Crops which strike deep and occupy the ground long, should be succeeded by plants which pierce but a little way under the surface.

Q. Does garden soil require REST between the different rotations?

A. No soil to which manure can be applied *ever requires* what is called *rest.* The soil never becomes, as it were, *tired of producing;* all it requires is to be refreshed with those substances which may have been consumed by the plants it has nourished. If left unsown by the hand of man it will produce rotations of weeds rather than be at rest.

Q. Is it not desirable to have within the year as MANY ROTATIONS as possible?

A. The greatest profit is drawn from gardens in which the crops are raised and consumed *in rapid succession.* The market gardener, who can clear out a square of any sort of vegetables in a single week, and resow or replant it immediately with another kind of plants, makes more of his ground than the person who consumes his vegetables very slowly, and yet does not break up a square until the whole crop on it has been cleared off. The season for a new crop is often lost by such delay.

SECTION III.—PROPAGATION OF FRUIT-TREES.

Q. How are FRUIT-TREES raised?

A. Fruit-trees are raised from *seeds*, by *grafting* and *budding*, by *cuttings* and *layers*, *suckers* or offsets, and *slips.*

Q. Are fruit-trees GENERALLY raised from seeds?

A. Fruit-trees are *seldom* raised from seeds, except by nurserymen, when they want to obtain new varieties.

Q. Why are not fruit trees commonly raised from SEEDS?

A. Because there is no certainty that the seed of fruit-trees will produce a tree yielding the *same kind of fruit;* and also because a tree is much longer growing from seed than from any of the other modes just mentioned; for instance, an apple-tree which would be many years in growing from a seed, may soon become a bearing tree from a graft.

Q. What is GRAFTING?

A. Grafting is the *joining together* of a cutting of one tree to another, in such a way as that the tree on which the cutting is placed sends up its sap into the cutting, and makes it grow and become a tree.

Q. What is a cutting used in grafting CALLED ?

A. A "*scion ;*" and the stem on which this cutting is placed is called a "*stock.*"

Q. Must the stock and scion be of the SAME VARIETY of tree ?

A. By no means: the stock and the scion may be *different* as to variety, but they must be of the *same family of plants;* for instance, peach and apricot trees are often budded upon a plum stock, which answers better than the natural stock in many cases. The new tree thus produced partakes of the hardiness of the plum-tree, without losing the delicate flavour of its fruit. The varieties of the cultivated apple are grafted on the wild crab-apple stock ; and the most beautful varieties of roses may be budded upon the brier.

Q. What do we mean by BUDDING, in contradistinction from grafting ?

A. In *budding*, the *bud of one tree*, with a portion of bark adhering to it, is *introduced into the bark of another tree;* but in *grafting*, the *shoot is taken along with the bud and inserted in the stem;* whereas in budding nothing but rind is taken with the bud to be inserted in the rind of the stock. The budded tree will be a year slower in its growth than the grafted tree. Grafting is performed in spring, and budding in summer.

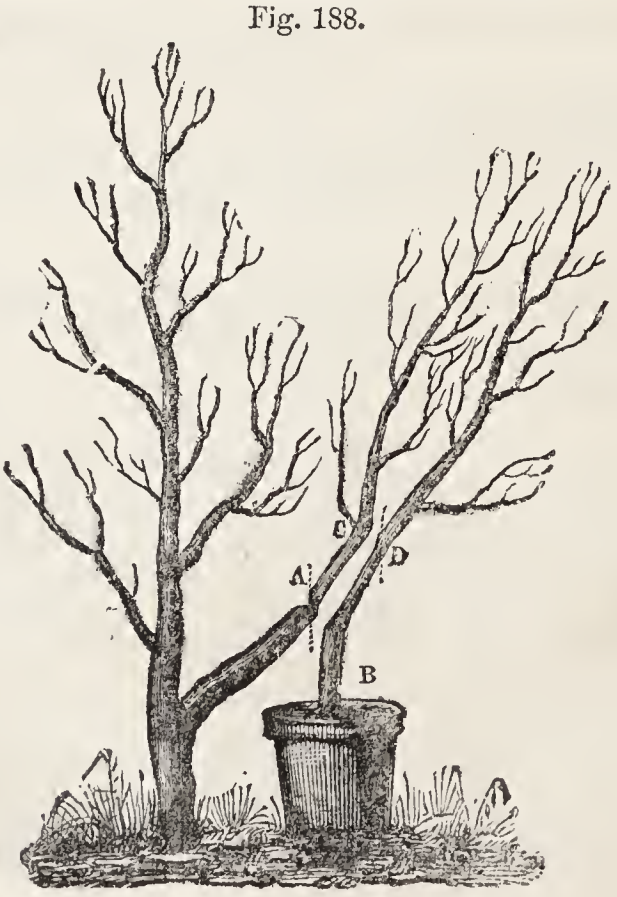
Q. Since trees, then, are raised more quickly by grafting than by budding, WHY are they ever BUDDED ?

A. Because *stone fruits* succeed better by budding than by grafting. Plants, also, of *very slender stems* will not bear the operation of grafting, though they will bear that of budding.

Q. Is there MORE than ONE METHOD of grafting ?

A. There are several methods. The French reckon *forty-three;* but many of these are more curious than *useful.*

Fig. 188.



Q. What is CROWN GRAFTING ?

A. Crown grafting is applied to *large limbs with thick bark*, or to large stems; in either case these are divided at right angles; the bark is raised by thrusting in a tapering, flattened piece of smooth hard wood or ivory between the wood and bark; this being withdrawn, the end of the scion, the plant to be grafted, is inserted and bound with a ligature. Some idea of the common process of grafting may be found by observing the foregoing engraving (*fig.* 188), the scion A C being grafted on the stock, as B D.

Fig. 189.

Q. What is CLEFT GRAFTING ?

A. Cleft grafting is performed by *splitting the stock across the top*, and inserting the scion cut like a wedge. (*See fig.* 189.)

Q. What is SADDLE GRAFTING ?

A. Saddle grafting is performed in a similar way to that of *cleft grafting*, except that the *stock*, instead of the *scion*, is formed like a wedge.

Q. What is meant by the STOCK and the SCION ?

A. The stock is the *plant* on which the grafting is made; the scion is the *stem* which is inserted into the stock.

Q. What are CUTTINGS ?

A. Cuttings are *small portions* cut from a *shoot of the preceding year*, with a few leaf buds on them. The shoots should be cut smoothly across, below a leaf bud.

Q. How are cuttings made to GROW ?

A. Some cuttings are put into a moderate *hotbed;* others into any *moist, loose earth* mingled with sand, but covered with handglasses, and shaded from the light until they have struck root. Some do not require any glass covering.

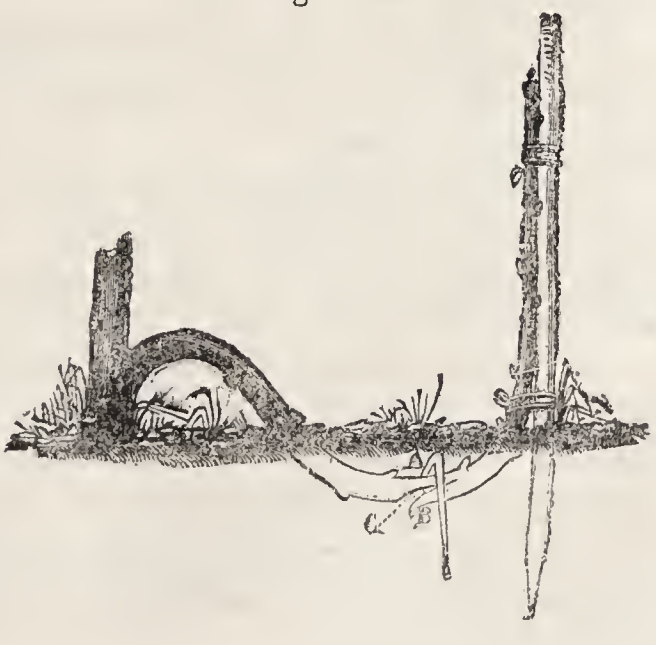
Q. At what SEASON of the year should cuttings be taken ?

A. Cuttings should be taken in *early spring*, before the sap has risen.

Q. What is LAYERING ?

A. Layering is the *bending down into the earth* of a branch (*see fig.* 190), after being cut about half way through, B, and slit upwards about half an inch from the cross cut, C; it is then pegged down to the earth, A, in which it will take root at the wounded part, if that be properly covered with earth.

Fig. 190.



SECTION IV.—FLOWERS AND WEEDS.

Q. How are flower plants CLASSED in a general way?

A. Flower plants are distinguished by the terms *bulbous*, *tuberous*, and *fibrous-rooted.*

Q. How are flowers PROPAGATED?

A. Flowers are propagated by *seeds*, *buds*, *layers*, *suckers*, *offsets*, *cuttings*, and by dividing or parting.

Q. What KINDS of FLOWERS are always raised from seeds?

A. The flowers called *annuals* are always raised from *seed.*

Q. What are ANNUALS?

A. Annuals are those which live during *one year* only.

Q. What are those plants called which are raised from seed ONE YEAR, bloom the NEXT, and then FAIL?

A. Such plants are called *biennials.*

Q. Have not ALL plants fibres?

A. *All* plants have *threadlike fibres*, which are, in fact, the mouths of the roots; but the plants we have last mentioned are especially distinguished as fibrous, because they have neither bulb nor tuber.

Q. What is a BULB?

A. A bulb is a *ball* consisting of either *scales* or *coats*, one within the other, which, when placed under ground, pushes forth a stem, roots, and all the other parts of a plant.

Bulbs are, in fact, underground buds: they can be removed from one place to another without injury; they contain within themselves the elements of future plants; their roots perish with their leaves in winter; and bulbs in that state are incapable of drawing any nourishment from the earth?

Q. What is a TUBER?

A. A tuber is a *plain*, *solid root*, like a potato; whereas a bulb is composed of scales or coats.

Q. How are tulips, and other bulbous-rooted flowers, PROPAGATED?

A. Bulbs are usually propagated by *offsets* from the main bulb.

Q. What are OFFSETS?

A. Offsets are *young bulbs* formed on the old one, and which, if broken off and planted, will grow.

Q. Is there any RULE to be observed respecting the SIZES of the pots in which plants are to be kept?

A. Plants should at first be put into the *smallest pots* they will grow in. This rule is particularly to be observed in the potting and shifting of annuals.

Q. What is meant by INFLORESCENCE?

A. It means *flowering;* but by this term botanists understand, not only the flower itself, but the various parts which belong to, and are united to it.

Q. How is a flower ATTACHED to the stem of a plant?

A. By a small branch called a *peduncle* or *pedicle.*

Q. What is meant by the phrase DEFINITE INFLORESCENCE?

A. It means that the *branch* or *stalk ends in a flower.*

Q. What is meant by INDEFINITE INFLORESCENCE?

A. A *flower stalk* which *gives off*, as it proceeds, *little flower shoots* on either side, but does not end in a flower.

Q. What are BRACTS?

A. Bracts are the *small leaves*, from the *axils* of which flowers grow.

Q. What do you mean by AXILS?

A. Axil, or axilla, is the angle formed by the junction of a leaf stalk with the stem or branch. The literal meaning is *arm-pit.*

Bracts, although their usual appearance is green, like a leaf, sometimes undergo very strange modifications. Thus the pineapple is, in reality, nothing more than an assemblage of fleshy bracts; and the scale of the fir cone is nothing more than hard leathery bracts. In proportion as bracts are developed nearer to a flower, so does their natural green colour give place to the colour of the flower itself. Occasionally, the flower actually springs from the upper surface of a bract, as is the case in the linden. (*See fig.* 191.)

Fig. 191

FLOWER OF THE LINDEN TREE.

Fig. 192.

RACEME OF THE CURRANT.

Q. What is meant by a RACEME?

A. The term raceme is applied by botanists to those *pedicles* which are almost *equal in length.* Black, red, and white currant trees are examples of this kind. (*See fig.* 192.)

Q. What is meant by a COMPOUND RACEME?

A. The term is applied to that form of flowering where the *pedicles grow from the stem;* but instead of each bearing at once a flower at the end, ramify a third and even a fourth time. Of this we have an example in the horse-chestnut. (*See fig.* 193.)

Fig. 193.

Q. What is the CORYMB ?

A. A kind of inflorescence in which the *lower* pedicles are much *longer* than the *upper* ones; and, consequently, end at the same or nearly the same level. (*See fig.* 194.)

Fig. 194.

CORYMB OF THE MOHALEB CHERRY.

Fig. 195

SIMPLE UMBEL OF THE COMMON CHERRY.

Q. What is meant by the UMBEL?

A. It means that kind of infloresence in which the pedicles are of the *same length*, and rise from the same part of the stem, stretching out like the ribs of an umbrella. (*See fig.* 195.)

Fig. 196.

Q. What is meant by the SPIKE?

A. The term is applied to that species of inflorescence in which the pedicles *are wanting*, and the flowers accordingly are *without stalks*, as may be seen in the *vervain*. (*See fig.* 196.)

Q. Mention the various NAMES given by botanists to the different parts of a flower.

A. The *whorls*, *calyx*, *petals*, *corolla*, *stamens*, and *pistils*.

Q. What is meant by the term WHORL?

A. A *circular row* or *round ring*. In examining a flower it is found to consist of several circular rows of organs, and to these are given the name of *whorl*.

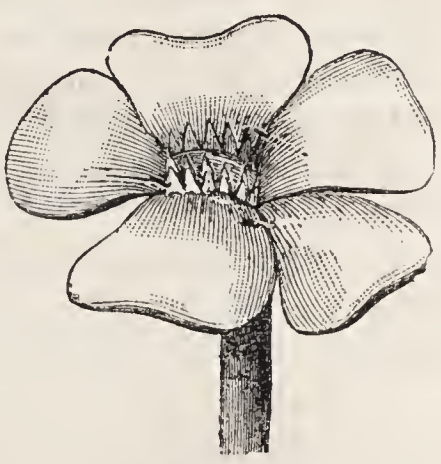
Q. What is a CALYX?

A. The calyx is the outermost whorl of a flower. It is formed of a number of parts called *sepals*, which are usually green.

Q. What are PETALS?

A. *Small leaves*, which *together* form what botanists call the *corolla of a flower*. (*See fig.* 197.)

Fig. 197.



COROLLA OF THE RANUNCULUS.

Q. What are STAMENS?

A. The term stamen is given to those whorls or circular rows of organs *within* the corolla; they are the *male* part of the plant. They are divided into a filament, or thread-like portion, with an antler or head. This antler or head is covered with a dust called *pollen*.

Q. What are PISTILS?

A. Inner whorls or circular rows of organs which spring from what is called the *ovary below*, and ending in what is called the *stigma above*; the intermediate part being called the *style*. The *pistils*, or *carpels*, as they are also called, are the *female* parts of the plant.

Fig. 198.

STAMEN OF THE RANUNCULUS.

Fig. 199.

CARPELS OF THE RANUNCULUS.

Q. What are to be considered as WEEDS in a garden ?

A. Any plants that grow in a garden *of themselves*, and are *not wanted there*, may be called weeds; thus, a potato-plant, though not a weed, would be deemed and treated as such if it intruded itself into a bed of flowers or into a row of peas. The presence of real weeds should not be permitted among any cultivated crops.

Q. Why should not weeds be ALLOWED to GROW with the crops ?

A. Because weeds *rob the crops* of much of the *nourishment* which the soil contains, and take up the room of valuable plants.

SECTION V.—DRAINING.

Q. What do you mean by the DRAINING of land ?

A. By the draining of land is meant the removal of the superabundant moisture by drains made in a regular manner.

Q. What are the COMMON CAUSES of excessive moisture in land ?

A. The common causes of excessive moisture in land are the *lodgment of rain water on a clay soil*, and *springs* bursting from their confinement in the undersoil to the surface, by reason of the closeness of the undersoil, which will not let them pass downwards.

Q. What is the EFFECT of warm rain falling on loose or porous land, on which, of course, moisture does not rest ?

A. Rain falling through warm air on porous land carries *heat into the free soil*, through which every drop passes easily, and thereby forces the growth of plants.

Q. What DEPTH of drain is generally recommended ?

A. The depth recommended for general drains is from *three to four feet ;* the outlet drains, to receive the water which runs from the others, must, of course, be deeper than these.

Q. Why would not drains of a LESS DEPTH answer the purpose ?

A. Shallow drains are less likely to *intercept any underwater* arising from land springs, and they do not afford sufficient *depth of dry soil* for the roots of such plants as grow deeply. The water

which flows from shallow drains after heavy rains carries with it sand, which is so precious in a clay soil, and manures also; and shallow drains do not cause such warmth in the undersoil as deep ones.

Q. But when the surface moisture becomes warmed by the sun, will it not conduct the warmth DOWNWARD into the soil?

A. Surface moisture does *not send down heat* when it becomes heated by the sun, for its heat rises upwards in vapour, being lighter than the air, just as the steam of water boiling in a pot rises upwards. In fact, moisture lodged in the soil prevents heat from entering into it.

GEOLOGY.

CHAPTER LXIII.

FORMATION AND STRUCTURE OF THE EARTH'S CRUST.

Q. What is GEOLOGY?

A. Geology is the *natural history of the earth.* It comprehends the *investigation of its structure*, and the *character* and *causes of the changes which, since its creation, have been continually going on* upon its surface, and in the organic and inorganic kingdoms of nature.

Q. What is the DERIVATION of the word "geology?"

A. It is derived from the Greek words γη, the earth; and λογος, a discourse. Thus the meaning of the word is a description of, or discourse upon, the earth; that is to say, an account of the earth as regards its structure, and the different changes it has undergone since its formation.

Geology admits of division into *descriptive* geology; *dynamic* geology, which treats of the forces by which the surface of the earth has been modified; and into *practical* and *economic* geology, embracing the application of geological science to mining, road-making, architecture, and agriculture.

Q. What is the FORM of the earth we inhabit?

A. The earth may be described as a planet, about *eight thousand miles in diameter*, and in *shape* resembling an orange.

Q. What is the DENSITY, or WEIGHT, of the earth, compared with the weight of an EQUAL BULK of WATER?

A. It is *five and a half times heavier* than an equal bulk of water.

Q. As the average density of all the materials upon the surface of the earth is only about three times greater than that of water, what INFERENCE can we draw respecting the INTERIOR of the earth?

A. That it is composed of materials which are *heavier than the materials which make up the surface*, probably metals.

Q. What PROPORTION of the earth's surface is covered by the OCEAN?

A. About *three-fifths.*

Q. How MUCH of the earth's surface may be considered HABITABLE by man?

A. Not more than *one-fifth*—a large part of the surface not covered by the ocean being occupied by vast bodies of fresh water, polar ice and snow, deserts, swamps, &c.

Q. What is the diameter of the earth from pole to pole?

A. Seven thousand nine hundred and sixteen miles.

Q. How many square miles are embraced upon the surface of the earth?

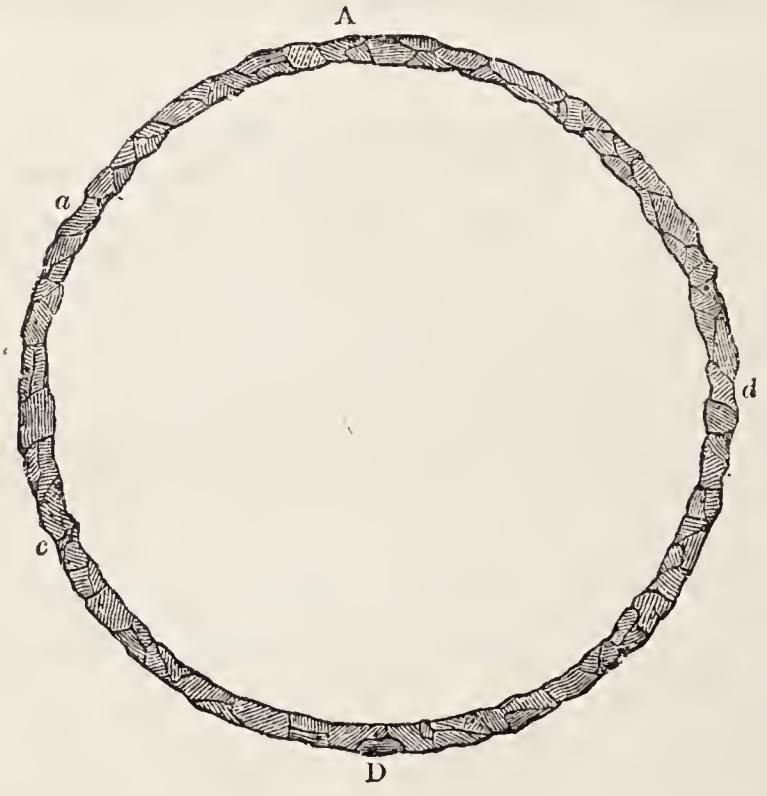
A. The surface of the globe is calculated at two hundred and eleven million square miles, of which about one hundred and fifty millions are covered with water, and sixty-one millions appear as land.

Q. What is that portion of the mass of the earth CALLED which man has been enabled to examine and study?

A. The *crust* of the earth.

The phrase "crust of the earth" involves many important principles in geology. The very word *crust* implies a surface that has undergone some process of hardening, and that retains beneath it some materials in a condition different from itself.

Fig. 200.



The above illustration represents the first hardening of the crust of the earth. The phrase *crust,* in geology, implies that the whole body of the earth was once in a state of fusion; that it was once all in a melted state—glowing, burning, and flaming; and that it gradually cooled, until a crust, or surface, hardened all over it. The crust of the earth is at least four hundred miles in thickness. In observing this crust, as shown in the engraving, it will be observable that the outer lines are not even, but rugged. The outer line of the circle is full of dents and hollows, and of swellings and points. Every one of these indentations, marked *a, c, d,* represent deep hollows, or extensive valleys, some miles deep, and sufficient to form the bed of a gulf, or inland sea. The varied changes of weather and falls of rain would materially alter the form of these indentations; sea would be made to join sea, and oceans formed; and land would be elevated by sand being deposited in layers at the bottom of the floods.

Q. What is the THICKNESS of this crust?

A. The thickness of the earth's crust, from the highest mountain peaks to the greatest natural or artificial depths, is about 400 *miles.* As the entire thickness of the earth, from A to D (*see fig.* 200) is nearly 8,000 miles, that portion of its structure which man has explored is therefore insignificant compared with the magnitude of the whole.

Q. What is the FIRST important geological fact which it is necessary to learn?

A. That the earth was at first a *mass of melted matter*, which has gradually *cooled at the surface*, and is now covered with a *crust.*

Q. Has not all MELTED MATTER a tendency to EXPAND?

A. Yes; and the *heat* of the melted matter beneath the crust of the earth's surface has *materially changed its form* in many important respects.

Q. What CHANGES are thus effected?

A. *Masses of matter are upheaved*, and *fissures* or *openings* are made in the earth's crust.

Q. What OTHER CHANGES take place in the earth's surface?

A. Other and important changes are produced by *water* in the *formation of seas, oceans, &c.*, and the carrying deposits of sand to lower levels.

Q. What is the HEIGHT of the most elevated mountain summit upon the earth's surface?

A. The mountain Dhwalagiri, the highest peak of the Himalayas, in Central Asia, is estimated at *twenty-eight thousand feet above the level of the sea*, being *more than five miles* of perpendicular altitude.

Q. What is the greatest NATURAL DEPRESSION upon the earth's surface?

A. During the year 1853 soundings made in the South Atlantic Ocean showed a depth of *seven thousand seven hundred fathoms*, or about *eight miles.* This is the greatest depression known to exist upon the earth's surface.

Q. What are ROCKS?

A. Rocks, in geology, are the *mineral masses which compose the crust of the earth.* The term rocks includes not only those masses which are in a solid state, as granite, limestone, &c., but all those materials which are soft and yielding, as beds of clay and sand.

Q. What is the COMPOSITION of rocks?

A. They consist principally of combinations of *iron*, *lime*, and *silex* or *silica*, the latter substance forming nearly one-half of all the materials composing the crust of the earth.

Q. Into what TWO great CLASSES are rocks divided?

A. Into *stratified rocks* and *unstratified rocks.*

Q. When are rocks said to be STRATIFIED?

A. When they are divided into *beds*, like the *leaves of a book*, or

several books, or pieces of cloth, piled upon each other, they are said to be stratified.

Q. The stratified rocks are also denominated AQUEOUS rocks : WHY have they received this designation ?

A. Because they were evidently *deposited from water*, where, for the time, the substances of which they were composed were either chemically or mechanically suspended.

Q. When are rocks said to be UNSTRATIFIED ?

A. When *no traces of beds* or *layers* can be detected, and the rock forms merely a *great mass* of mineral matter, it is said to be unstratified.

Q. If the mud and sand deposited by rivers, or other bodies of water, at the present time, were hardened into rocks, would the rocks so formed exhibit STRATIFICATION ?

A. They *would ;* water holding matter in suspension *deposits the heaviest particles first*, and afterwards the lightest. Bodies of water are sometimes charged with clay, and again with sand, owing to inundations or rains. These different substances would consequently be deposited in separate layers, one upon the other. Hence we infer that rocks consisting of layers, or strata of different thickness, and often of different materials, resting parallel upon each other, have been deposited from water.

Q. The unstratified rocks are also denominated "IGNEOUS OR PLUTONIC rocks :" WHY have they received this designation ?

A. Because they have evidently been in a *melted or fused state* through the action of *intense heat.*

Q. What are EXAMPLES of the igneous rocks ?

A. Granite, the *crystalline limestones or marble*, *trap*, *serpentine*, *quartz*, *lava.*

Q. What EVIDENCE have we that these rocks were once melted ?

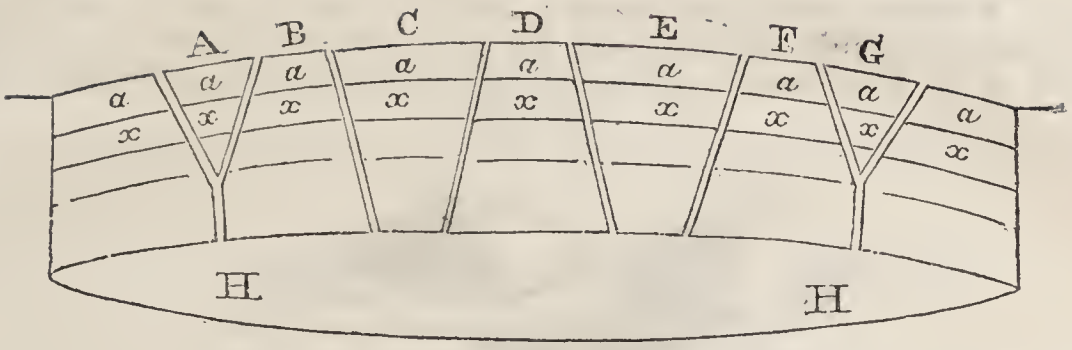
A. They *penetrate* other rocks in the form of *veins*, they possess a *crystalline structure*, and are *destitute of any layers* or definite order of arrangement. They form great masses of mineral matter, without symmetry or shape.

Q. May not some of the so-called "igneous rocks" have been also DEPOSITED from WATER, and been originally STRATIFIED ROCKS ?

A. Many of the igneous rocks *were undoubtedly deposited from water* originally in a stratified form, and have been *subsequently changed*, and caused to assume their present appearance through the *agency of heat.*

On the intensity of heat below the earth's surface would depend the thickness of the crust. All melted matter has a tendency to expand, or rise ; and accordingly the melted matter within the earth acquires an elevating force, which causes the mass that lies on its surface to swell out in the form of a curve. In this process the heat produces many cracks and fissures. If we imagine that the crust of the earth were cut through, so that we could see the face of it, the cracks and fissures would then appear like those seen in the accompanying diagram ; and the body of the crust would appear between the different fissures something like wedges whose sharp points had been cut off. The burning heat,

Fig. 201.



which has produced this wedge-like appearance, now applies its elevating force to the different masses. The wedges B, D, F, with their strata *a x*, present larger surfaces to the fire H than the wedges A, C, E, G, with their strata *a x;* therefore the elevating force of the fire will have greater power on B, D, F, G, than on A, C, E; and, in consequence, will push them up above the others.

But, in studying the causes which have produced the earth's crust, and the varieties which it exhibits, we have not only to find out the cause of the first hardening of the earth's surface by cooling, and the action of subterranean heat in upheaving masses of matter on the surface; we have also to consider the action of water in dissolving and wearing away portions of upper rocks, and carrying down the sand to deposit it at a lower level.

Q. How does LAVA differ from other igneous rocks?

A. Lava is the product of *melted rocks* thrown out in a *fluid* or *partially fluid state by volcanoes*, within a comparatively recent period. It is not generally so compact and dense as the other igneous rocks.

Q. What is the "DIP" of stratified rocks?

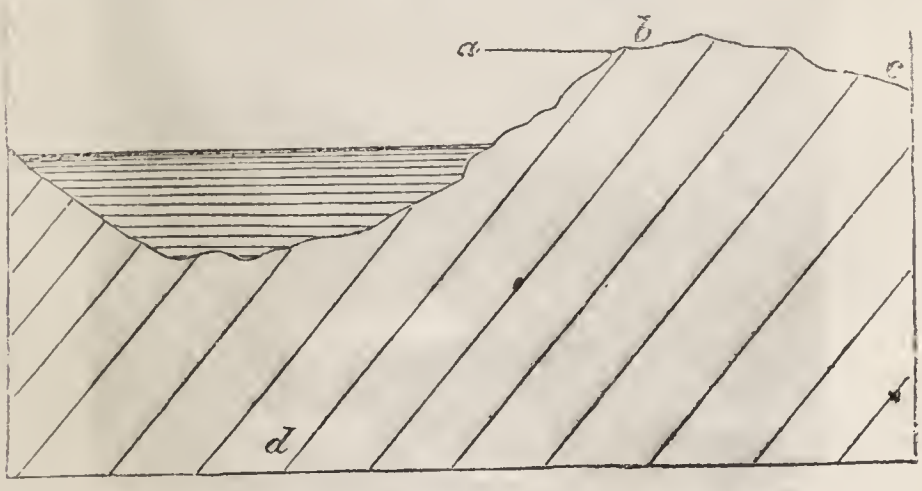
A. The various rocky strata are *not usually horizontal* in their position, but *inclined* at various angles. The course in which water poured on an inclined stratified layer would descend, is called, in geological language, the *fall* or *dip* of the strata. The direction of various strata is designated by the term *strike.*

Q. When are strata said to CROP OUT?

A. When they *come to the surface of the earth.*

In fig. 202, the line *b d* is the direction or dip of the strata, and the angle *a b d*, which the strata forms with the horizon, is called the angle of inclination. The exposed edge *b c*, where the strata come to the surface, is called the *outcrop*, and the line of outcrop *a b*, on a horizontal surface, is called the strike of the strata.

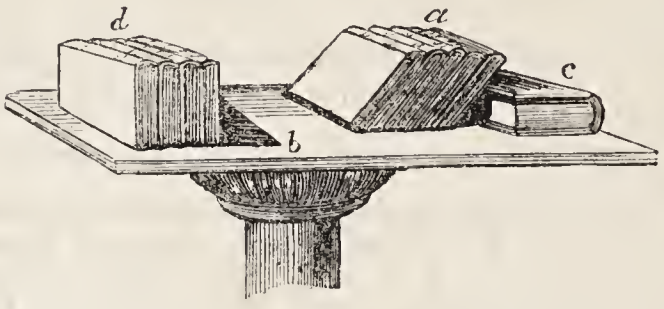
Fig. 202.



The dip and strike of the strata may be farther illustrated by reference to fig. 203, in

which *b* represents a table on which some books, *a*, are made to rest in a slanting position by means of another book *c*, laid flat on the table. If we now consider the top of the table to represent a horizontal plane, and the books beds of rock, then the angle which the sides of the tilted books *a* make with the table *b*, would be called their dip, and

Fig. 203.



according to the amount of the angle would be the amount of dip—that is, the less the sides of the books sloped, the less the dip; and, conversely, the more upright they were, the greater the dip. The book resting flat upon the table would be said to be horizontal, and have no dip at all. Let *d* be books standing upon the table with their backs upwards, their strata, or beds of rock, which occur in similar position, would be termed vertical.

The strike, or direction of the beds or strata, being a line at right angles with their dip, the lines which the back of the books *a* and *d* would take towards the north, south, or other points, as the case may be, would represent the strike, or direction. Let us farther suppose that the backs of the books *d* are arranged parallel to those of the books *a*; then the strike, or direction of any beds of rock, situated as *a* and *d* are, would be the same, notwithstanding the beds at *d* would be vertical, while those at *a* would have a dip.

Q. What is GRANITE?

A. Granite is a rock frequently of a *light-gray colour*, composed of *three distinct minerals*, quartz, feldspar, and mica, in various proportions, confusedly crystallised together.

Q. What is a TRAP rock?

A. Trap rocks are *principally composed of feldspar* and *hornblende*, with some iron and other mineral substances. It is a black or greenish-looking rock, and some varieties are known as greenstone.

Fig. 204.

THE GIANTS' CAUSEWAY.

Q. Can you give some NOTED EXAMPLES of trap rock?

A. The *Giants' Causeway*, on the north coast of Ireland, is composed of a variety of trap called basalt; the *Palisades upon the Hudson*, in America, are composed of trap.

This rock has a tendency to crystallise in large columnar masses, the appearance of which is represented in fig. 204.

Q. In WHAT PART of Ireland is the Giants' Causeway?

A. In the neighbourhood of *Balimony*, county Antrim.

Q. What is the GENERAL APPEARANCE of the causeway?

A. The *principal* or *grand causeway*—there being several considerable and scattered fragments of a similar nature—consists of an irregular arrangement of many hundreds of thousands of columns formed of a black rock nearly as hard as marble.

Q. Are these columns EQUAL in HEIGHT?

A. No. They are of an *unequal height and breadth;* several of the most elevated, visible above the surface of the strand, are about twenty feet. How deeply they are fixed in the sand has never been ascertained.

Q. What is the EXTENT of the principal causeway?

A. As it is visible at low water, it extends for *nearly two hundred yards;* the breadth of the principal causeway is from *twenty* to *forty feet.*

This is exclusive of the broken and scattered pieces of the same kind of construction, which are detached from the sides of the grand causeway, as they do not appear to have been contiguous to the principal arrangement, although these have been frequently comprehended in the width, which has led to such a diversity in the accounts of its dimensions. Its highest part is the narrowest, and there its width is not above twelve to fifteen feet. The columns of this narrow part incline from the perpendicular a little to the westward, and form a slope on their tops by the unequal height of their sides; and in this way a gradual ascent is made at the foot of the cliff, from the head of one column to the next above, to the top of the great causeway, which, at the distance of about eighteen feet from the cliff, obtains a perpendicular position, and, lowering from its general height, widens for nearly three hundred feet above the water. The tops of the columns, being equal in height, form a grand and singular parade, which may be walked on safely.

Q. What is the FORM of the PILLARS of the Giants' Causeway?

A. With some few exceptions, they are *pentagonal, having five sides.* They are not of one solid stone in an upright position, but composed of several *short lengths joined together.*

Q. What is a SANDSTONE?

A. A sandstone is a rock consisting of *grains* or *small rounded fragments* of any other rock, most frequently of silicious rocks. These particles are consolidated, sometimes without any visible cement, but often by an argillaceous (clay) or calcareous (lime) substance.

Q. When the rock consists of large rounded pebbles, or stones cemented together, what is it CALLED?

A. Conglomerate, or *puddingstone.*

Q. When the rock consists of fragments that are NOT ROUNDED, or CEMENTED together, what is it CALLED?

A. Breccia.

Q. What is CLAY?

A. Clay consists of a mixture of *silicious* and *aluminous earth.* It is tough, easily moulded, and generally of a bluish colour.

Q. What is CLAY SLATE?

A. *Clay hardened into rock.* When the rock is partially solidified it receives the name of *shale.*

Q. How may all the varieties of ARGILLACEOUS (clayey) rocks be DISTINGUISHED?

A. When breathed upon they give forth a peculiar *earthy smell.*

Q. When is a rock said to possess a SLATY STRUCTURE?

A. When it *splits easily in one direction*, in consequence of its component parts being arranged as laminæ in parallel layers.

Q. What is the BUILDING MATERIAL, so much used, which is called FREESTONE?

A. A fine variety of *sandstone.*

Q. What NAME is given to the confused masses of SAND, GRAVEL, and DETACHED ROCKS which occur heaped together upon the earth's surface?

A. *Diluvium.*

Q. What NAME is given to the fine coating of soil which overlies the coarser sand and gravel—that part of the earth which is capable of cultivation?

A. *Alluvium*, or *alluvial* deposits.

Q. What are BOULDERS?

A. Boulders are *detached rocks*, generally of a rounded form, confusedly scattered over the surface of the earth. The appearance of boulders is represented in fig. 205.

Fig. 205.

Q. Are BOULDERS found in ALL PARTS of the world?

A. They are found in *Russia*, *Poland*, *Germany*, *Holland*, *England*, *Ireland*, *Canada*, and *North America*, scattered over broad plains and mountain steeps.

Q. How do geologists ACCOUNT for these boulders?

A. There can be no doubt that all the boulders have come from

the *North*, for their course, both in Europe and America, is found to be either due north and south, or varying a few degrees to north-west and south-east.

Boulders, containing specimens of almost all known rocks, are found in the eastern counties of England. Some of these could have come only from Norway and Sweden; for Sir Charles Lyell traced them from these two countries to Denmark, across the Elbe, through Westphalia, to the borders of Holland. "We need not," he says, "be surprised to find them re-appear on our eastern coast, between the Tweed and the Thames—regions not half so remote from Norway as are many Russian erratics from the source whence they came." As it is evident that very many of these boulders, in different parts of the world, are fragments of rocks which do not exist in those localities, the question, Whence came they? is most important and interesting. They have been torn from rocks far away—they are strangers in a strange land. How did they get there? Various answers have been given.

Q. By WHAT MEANS have these boulders been distributed over the face of the earth?

A. Amongst the answers which have been given to this question, we may mention three:—

1. That they were swept away from the rocks and borne to foreign shores by the Great Flood—the universal deluge—in the time of Noah.

2. That they were transported at intervals by the recurrence of partial floods.

3. That icebergs were the means of their removal from place to place.

The iceberg theory has its difficulties, as well as the others; but it seems to come nearer the true cause of the phenomenon. It has been proved that all these boulders have come from the north. It has also been ascertained that, at an early age in the history of our globe, the northern hemisphere was much colder than it is now, and that this intense coldness took place suddenly. Such a lowering of the temperature would fill the glens of the polar region with immense glaciers; these glaciers would start out into the northern sea. Icebergs, detached or broken off from these glaciers, would convey to a distance huge masses of rock, which water alone could never have moved. As the lower surface of the icebergs would either be abraded by the action of the sea, or melted by the increased temperature in the south, the masses of clay, sand, gravel, and boulders, which they had brought down as glaciers or imbedded as coast ice, would drop down, and be scattered over the bottom of the sea. Ages after the deposit of these rocks and sands, they, by volcanic action, would be elevated above the level of the sea, bearing on their edges and sides the boulders that had thus been deposited. Such is a bare outline of the iceberg theory.

Q. Does geology throw any light upon the ORIGIN and CREATION of the earth?

A. Respecting the origin and creation of matter geology affords no information; it teaches clearly, however, that there was a *beginning;* that there was a period when *no vegetable or animal existed* upon the surface of the earth; that the *lowest forms* of vegetable and animal life were *first called into existence*, which were gradually followed by other and higher organisations; and that, finally and lastly, *man* became an inhabitant of the earth.

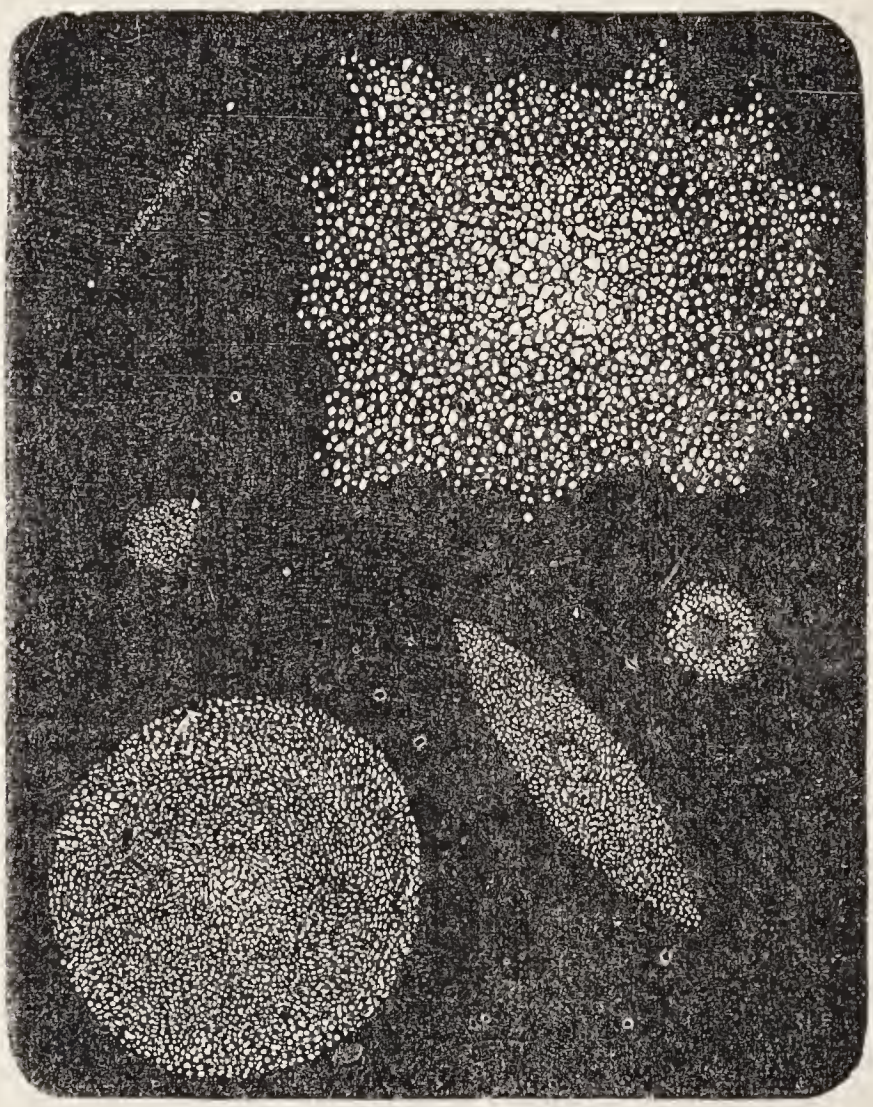
Q. Can we form any IDEA of what is meant in revelation by the assertion that the earth at one time was "without FORM, and VOID?"

A. There is some reason to believe that the material of which the earth was composed was once in the *condition of the nebulæ;* that it *floated as a vapour in space;* and that, through the influence of *gravitation*, *cohesion*, and *chemical action*, it was moulded in the form of a *sphere.*

Q. What is the APPEARANCE of nebulæ?

A. Some of the nebulæ seem to be *mere clouds of thin vapour*, without definite shape; others seem to be *condensing* into *spheroidal masses*, and present a dense *central nucleus* of light, surrounded by a luminous halo; in short, a series of them may be traced from mere *films of vapour* to *dense masses*, which have the appearance of a star surrounded with a haze. Fig. 206 represents the appearance of various nebulæ, as seen through powerful telescopes.

Fig. 206.



VARIOUS FORMS OF NEBULÆ.

Q. What are the NEBULÆ supposed to BE?

A. *Worlds in the process of formation.*

Q. If the earth was once in the state of vapour, or nebulous matter, and this matter was gradually condensed, what CONDITION would matter FIRST ASSUME in its progressive condensation?

A. A *fluid condition.*

Q. Have we any REAL EVIDENCE that the earth ever was FLUID?

A. Geology commences its revelations at this point, and teaches most clearly that there was a period when *all matter comprising the earth was in a fluid or liquid condition.*

Q. What are the EVIDENCES which geology presents to us in relation to the former fluidity of the earth?

A. The fact that *all the primitive rocks* exhibit evidence that they were *once in a melted condition;* that the earth is a *spheroid*, and not a *sphere;* and that the *centre* of the earth is at the present time a *great source of heat.*

Q. What do we mean by the PRIMITIVE ROCKS?

A. The *lowermost rocks*, those which constitute the *foundations* upon which all the *stratified rocks rest.* They also attain the *highest elevations* on the surface of the globe. *Granite* and its varieties are *types* of the primitive rocks.

Q. Why are they called PRIMITIVE?

A. Because it was inferred, from the entire absence of any remains of vegetables or animals in them, that they had been *formed before the creation of animals* or *vegetables;* but it is now ascertained that granite and its associated rocks are of *various ages*, and in some instances have been formed from stratified rocks melted by intense heat.

Q. How does the fact that the earth is a SPHEROID, and not a sphere, show that it was ONCE FLUID?

A. A *spheroid* is the *form* which a *fluid body* will always assume when *caused to revolve about its own axis.* The earth has exactly the form which it must have assumed had it been once a fluid in a state of revolution about its own axis.

Q. How do we know that the CENTRE of the earth is at the present time a SOURCE of HEAT?

A. The existence of a *great number of volcanoes* in all parts of the earth's surface—some of which are *constantly sending forth melted rocks and fire*—proves that the interior of the earth contains great reservoirs of heat, the sources of volcanic supply. It is also a fact that, as we *descend* into the interior of the earth, the *temperature regularly increases;* the existence of *boiling springs* in all countries also afford evidence of the central heat of the earth.

Q. Does the heat INCREASE as we descend into the earth?

A. After passing the first hundred feet the mercury in the thermometer begins to rise, and continues to rise the lower we descend.

Q. Are ALL SPRINGS that rise from a very great depth in the earth more or less WARM?

A. They *are.*

Q. If the theory of the central heat of the earth be true, what is the CONDITION of the SURFACE upon which we live?

A. It is merely a *hardened crust*, resting upon a vast interior mass of *melted fiery matter.*

Q. Why has not the earth COOLED DOWN in the lapse of ages, and parted with its heat?

A. The *external portions* of the earth doubtless *cooled speedily*, and, deprived of their heat, became solid. The crust so formed, consisting

of earth and rock, on account of its bad conducting power, would effectually retain the heat of the central portions, and prevent its passing into space.

Q. How may the MATTER composing the earth be supposed to have originally ACQUIRED its HEAT?

A. Vapours, in passing into liquids, and liquids in becoming solid, *develop large quantities of latent heat.* The heat liberated during the condensation of the nebulous matter to a solid form would undoubtedly be sufficient to account for all the phenomena made known to us by geology.

Q. Does the MOON, when examined by a powerful telescope, present evidences of VOLCANIC or IGNEOUS action?

A. This satellite of the earth, which appears so plane and even, becomes, under the telescope, *studded with rough and ragged mountains*, whose tops resemble the *craters of volcanoes*, or the sharp, conical peaks of the terrestrial volcanoes Cotopaxi, Etna, Vesuvius, &c.

Fig. 207.

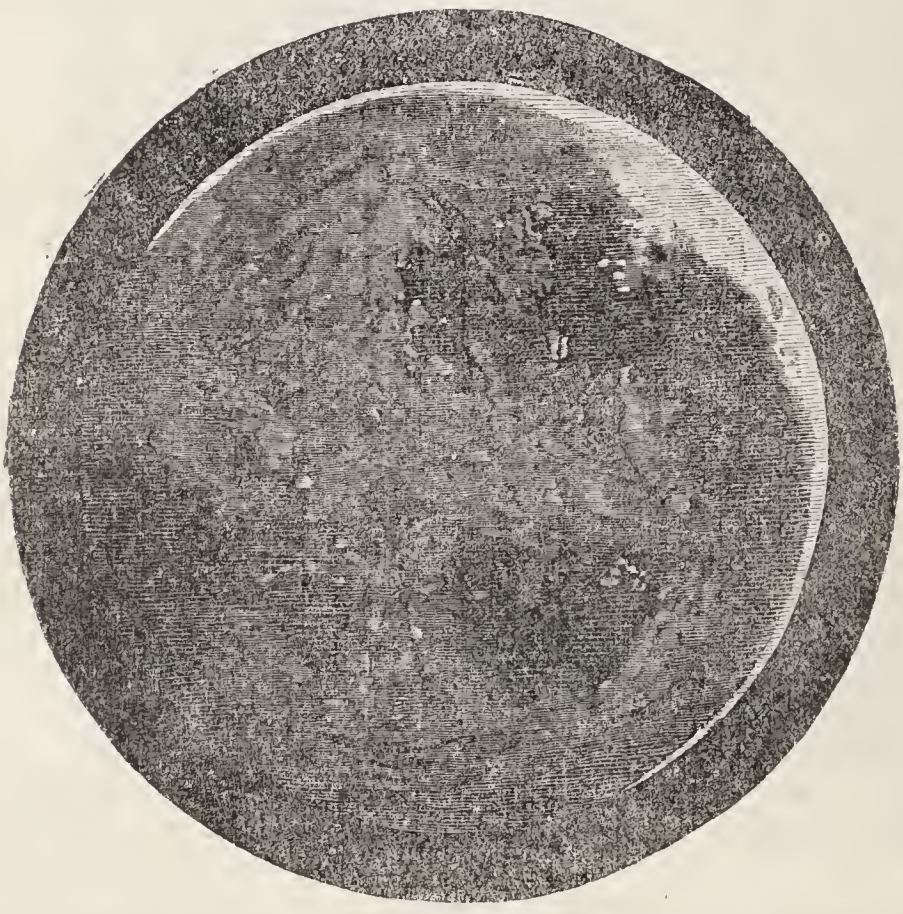


Fig. 207 represents the appearance of the lunar surface as seen through a large refracting telescope, when the moon was full. The moon is apparently but a smaller pattern of the earth, exhibiting upon its surface the effects of a more intense volcanic action; a fact which is probably due to the absence of water—an agent which, upon the earth, has so modified its surface, that its original igneous character is concealed in part beneath the sedimentary, aqueous, or stratified rocks.

Q. As we descend into the earth, what SPECIES of ROCKS do we uniformly find occupying the LOWEST positions?

A. The *igneous* or *primary rocks*—rocks which have the appearance of having been melted and fused.

Q. Have we ANY REASON for supposing that rocks of any different character lie BENEATH the igneous rocks?

A. The igneous rocks, occupying the lowest position in the crust of the earth, are undoubtedly the result of the *solidification* or *cooling of the earth's surface* in the first instance, and have remained unchanged and unaltered. We have, therefore, no reason for supposing that rocks, or materials of essentially different character, exist at any greater depth.

Q. What is the CHARACTER of the rocks immediately overlying the primitive or igneous rocks?

A. We find immediately above them rocks which are *stratified*, and have resulted from the deposition from water of matter which has been worn away from the surface of the granitic or primitive rocks.

Q. Why do we suppose that these rocks were formed SUBSEQUENTLY to the granitic or primary rocks on which they rest? why may not both have been formed at the SAME TIME?

A. Because *they contain fragments*, and are evidently made up of the *ruins* of granitic rocks; consequently, the latter must have had a prior existence. Again, it is natural to suppose, that when one layer of rock, of a certain composition, is superimposed upon a layer of rock of a different composition, that the latter must have been formed first.

Q. What is the CHARACTER of the rocks immediately resting upon the primary rocks?

A. They comprise the well-known rocks *mica slate*, *clay slate*, *talcose slate*, and *gneiss*, which last resembles granite, with the exception that it is stratified, and occurs in beds, which is not the case with granite. These rocks are of *great thickness*, are *destitute of all organic remains*, and appear to have been deposited in *layers* from water, and afterwards *hardened* by the *action of heat*.

Q. What NAME has been given to rocks of this class?

A. They are called *metamorphic*, because they have been changed, and have lost their original character through the action of heat. They are also termed *non-fossiliferous* or *azoic* (wanting in life), and, by some, transition rocks, from their forming a connecting link between the primary and more recent formations.

Q. Rising in the series, what is the CHARACTER of the rocks SUCCEEDING and RESTING UPON the metamorphic rocks?

A. The series of rocks resting upon and succeeding the metamorphic are *all stratified*, and *contain fossils* in great numbers and variety.

Q. What is a FOSSIL?

A. Any *organic substance.* The *remains or product of an animal or vegetable, imbedded in a geological formation*, is called a fossil. Fig. 208 represents the fossil remains of the chalk formation.

The most conspicuous of the fossils found in the chalk are shells of animals that

Fig. 208.

ORGANIC REMAINS OF THE CHALK FORMATION.

formerly lived at the bottom of the sea; coral, and other species. The names they bear are as follows:—1. Hippurites organisans; 2. Cidaris diadema, or Diadema rotulare (Agassiz); 3. Terebratula semiglobosa; 4. Turrilites catenatus; 5. Scaphites equalis; 6. Ammonite; 7. Crioceras puzosianus.

Q. What is the STUDY of fossils called?

A. The study of fossils is called *Palæontology* (from *palaios*, ancient, and *ontology*, the science of being). To become versed in the science requires an acquaintance with the principles and minute details of zoology and botany. Many of the general conclusions derived from the study of fossils may, however, be readily understood without this knowledge.

Q. In WHAT MANNER have fossils been PRESERVED?

A. When any organic substance is imbedded in earthy material which is slowly changing into rock, it may either *remain entire;* it

may be removed by *the infiltration of water*, or other causes, so gradually, as to leave its form and even its most delicate markings in the rock; or some *mineral substance* may be *substituted in place* of the original animal substance, and fill the space it once occupied; so that we sometimes find the organic substance itself, sometimes the mere impression of it, and again a cast of it.

Q. What NAME has been given to the rocks resting upon and succeeding the metamorphic rocks?

A. As a whole they are called the *fossiliferous* rocks; but they are divided into *nine* distinct and separate divisions, systems, or formations.

Q. What does the term "FORMATION" mean in geology?

A. We apply in geology the term formation to any portions of the earth's crust, of greater or less thickness, which were formed under the *same contemporary influence.* Formations which, in consequence of their close proximity, stand in mutual relations to each other, are considered by the geologist as connected groups; the separate layers constituting a formation are called its members.

Q. Will you enumerate the NINE distinct SYSTEMS, or FORMATIONS, into which the FOSSILIFEROUS rocks are DIVIDED?

A. 1. The *Lower Silurian:* this formation is most extensive, no less than eight departments of which have been made out by geologists in North America, composed of various limestones and sandstones;

2. The *Upper Silurian;*

3. The *Devonian*, or *Old Red Sandstone;*

4. The *Carboniferous* or *Coal* formation;

5. The *Triasic*, sometimes called the *New Red Sandstone*, and sometimes the saliferous formation, from the fact that it contains in Europe the principal mines or deposits of rock salt.

6. The *Oolitic* formation;

7. The *Cretaceous* or *Chalk* formation;

8. The *Tertiary* formation; and

9. The *Diluvium* or *Drift*, forming the most superficial deposits, and extending over a large portion of the northern countries of both hemispheres. Above the drift occurs the alluvial deposits—the soil we cultivate.

Each of the formations enumerated indicates an entirely new era in the earth's history; while each of the layers that compose a formation indicates but some partial revolution, or change.

Q. How are these different rocks DISTINGUISHED from each other?

A. First, by the *difference of their fossils;* secondly, by their *position;* and, lastly, by the *difference in the composition* of their *constituent materials.*

Q. How are they distinguished by the difference of their FOSSILS?

A. Each system represents a *period of time*, during which the rocks included in it were gradually deposited and formed at the bottom of

an ocean. During this period races of animals and vegetables came into existence, lived, flourished, and became extinct, leaving, as the only memorials of their existence, forms impressed or embodied in the rocks.

Q. Does each system of fossiliferous rocks appear to contain remains of animals and vegetables PECULIAR to ITSELF ?

A. It *does.* Not one species of fossil occurring in the silurian rocks occurs in the carboniferous (coal); the fossils of the old red sandstone are totally distinct from those of the cretaceous (chalk) system; while none belonging to the latter are now living upon the surface of the earth.

Q. Can a geologist, conversant with fossils, TELL at ONCE from WHAT SYSTEM a species is derived by mere inspection of it ?

A. As respects the common species of fossils, he *can readily determine at the first glance* from what system of rocks they have been derived, no matter if the fossil may have been obtained in a *remote portion of the earth;* for the reason that the fossils of each system possess characters peculiar to themselves.

Q. How does the POSITION in which the various systems occur serve to IDENTIFY and DISTINGUISH them ?

A. Each system maintains a certain *invariable order* and *arrangement.* Unless the strata have been torn up and lifted by volcanic forces, we never find rocks of a lower system resting upon those of one higher in the scale.

Strata of the silurian system are never found naturally covering those of the carboniferous system ; neither do the rocks of the coal period rest upon those of the tertiary period.

Q. As these various systems rest one upon the other, is not the arrangement of the rocks, comprising the crust of the earth, SIMILAR to the ARRANGEMENT exhibited by the several CONCENTRIC COATS of an ONION ?

A. If the various systems extended *uniformly* over the whole surface of the earth, and had *never been broken or disrupted*, they would enclose one another in a manner similar to the coats of the onion; but they do *not* extend thus uniformly.

Q. What is the REASON that the various systems of the stratified rocks do not extend UNIFORMLY over the whole surface of the globe ?

A. Because the *agencies concerned in their formation* did not operate at all places at the *same time.* The stratified rocks were formed at the bottom of an ocean from matter deposited by its waters. On those portions of the globe not covered by water at that period of time no such deposition could take place; and consequently we find particular systems restricted to particular portions of the earth's surface.

All the formations are not always found, or are not developed to the same extent, in all places. It is the same with the several strata of which they are composed. In other words, the layers of the earth's crust are not continuous throughout, like the coats of an onion. There is no place on the globe where, if it was possible to bore down to its centre, all the strata would be found. It is easy to understand how this must be so. Since irregularities in the distribution of water upon the land crust have, necessarily, always existed to a certain extent, portions of the earth's surface must have been left dry at

every epoch of its history, gradually forming large continents and islands, as the changes were multiplied. And since the rocks were mostly formed by the subsidence of sediment in water, no rocks would be formed except in regions then covered with water. They would be thickest at the parts where most sediment was deposited, and gradually thin out towards their circumference. We may, therefore, infer that all those portions of the earth's surface which are destitute of a certain formation were dry land during the epoch of the earth's history to which such formation relates, excepting, indeed, where the rocks have been subsequently removed by the action of water or other causes.—*Agassiz.*

Q. How does the DIFFERENCE of material constituting the different rocks serve, in some measure, to IDENTIFY them?

A. Because certain materials are found as *exclusive constituents* only of *certain systems.* Thus the occurrence of *beds of chalk* characterises and gives name to the *cretaceous* system; and the occurrence of extensive *beds of coal* indicates that the adjacent rocks belong to the *carboniferous* system.

CHAPTER LXIV.

EXISTING AND RECENT GEOLOGICAL CHANGES.

Q. Are GEOLOGICAL CHANGES taking place on the surface of the earth at the PRESENT DAY?

A. Physical changes, often unappreciated by us, are *continually going on* upon the surface of the earth, which, operating on a large scale, and through an *extensive period of time*, are producing *results of great magnitude* and importance.

Q. What are the EFFECTS of STREAMS and RIVERS upon the surface of the earth?

A. They are continually *wearing away* portions of the *dry land*, and conveying it to the ocean.

Q. How much SOLID MATTER is annually brought down by the River Ganges, and carried into the ocean?

A. By careful experiments, it is estimated that the Ganges transports annually from the land to the ocean more than *six millions of tons* of solid matter.

Q. How much solid matter is annually discharged by the MISSISSIPPI RIVER into the Gulf of Mexico?

A. Upwards of *twenty-eight billions of cubic feet.*

Q. What BECOMES of all the SEDIMENT transported to the ocean?

A. It generally *settles in layers to the bottom.* If, by the agency of volcanic heat, or by chemical action, it should become hardened or solidified, it would exhibit all the appearances which the stratified rocks present.

Q. Would the ROCKS so formed contain FOSSILS?

A. They would contain the *greatest abundance and variety of organic remains of every description;* the wrecks of ships, the bones of

men, animals, and fishes, shells belonging to the ocean, and shells swept down from the land; trunks of trees, land-plants, and sea-weeds, with works of art.

Q. Would not an examination of the STRATA forming at the bottom of the GULF of MEXICO, with the ORGANIC REMAINS included in them, impart to us very exact INFORMATION respecting the PRESENT CONDITION of extensive portions of the earth's surface?

A. Such an examination would teach us the *character of the animals and plants now living* in the valley of the Mississippi; and the *remains of man* and the *works of art*, such as coins, earthen and glass ware, and other articles, would indicate the degree of civilisation which prevailed in countries adjacent to the Gulf of Mexico. In the same way, by examining the stratified fossiliferous rocks, we can tell the condition of the earth's surface at the time they were formed.

Q. Do we find the remains of MAN in any of the FOSSILIFEROUS rocks?

A. *Neither the bones of man nor any works of art* have ever been found in any of the fossiliferous rocks belonging to the various geological systems. It is only in the *modern formations*, the *alluvial deposits*, that the remains of man have been met with.

Q. What INFERENCE, confirming the TRUTH of REVELATION, can be rightfully deduced from this fact?

A. That man was the *last created animal*, and that a comparatively *recent period* only has elapsed since his first appearance upon the surface of the earth.

Q. Are great beds of LIMESTONE forming at the PRESENT DAY beneath the surface of the OCEAN?

A. The *reefs built by the coral insect are calcareous*, and extend over vast portions of the bed of the ocean. In the vicinity of New Holland a coral formation exists upwards of seven hundred miles in length. Upon the coast of Florida limestone rocks are in the process of formation, the action of the waves grinding the corals and shells to a fine powder, which is afterwards deposited and hardened into layers in quiet waters.

Q. Do rocks and stones GROW?

A. A rock or stone is an inorganic body, which can only increase in bulk by the *addition of matter, not belonging to it, to its outer surface.* Hence stones may be incrusted, or several may be changed into one, but they cannot grow.

Q. Cannot CRYSTALS be said to GROW?

A. They *cannot.* Crystallisation is the *building up of a fabric by the adhesion of particles of matter to other particles* already arranged in a *geometric order;* and we have easy methods by which we can greatly increase the size of any artificial crystals, by simply adding fresh coatings of the substances of which they are constituted; but they cannot be said to grow.

Q. How does ORGANIC GROWTH DIFFER from CRYSTALLISATION?

A. In organic growth, through the influence of the vital or living

phenomena, the inorganic particles dispose themselves into *cells by* collecting together, and these, again, by a similar process, into *tissues*. A crystal grows by *gathering matter from without*, by collecting *solid particles on its solid faces;* while a *leaf* grows by *absorbing gaseous elements*, and through the agency of the cells, assisted by light and heat, assimilates them into its own structure.

Q. What is a VOLCANO?

A. An *opening* in the crust of the earth, through which *fire*, *smoke*, and *melted matter* (*lava*) are *ejected*. Volcanoes are supposed to be connected with a great central mass of heated matter occupying the earth's centre.

Q. What is the FISSURE in the earth's crust through which volcanic matter is conveyed called?

A. It goes under various names; sometimes it is called the *vent*, sometimes the *chimney*, sometimes the *chasm*.

Q. WHAT PART of the volcano is called the CRATER?

A. The *upper part* of this vent or chimney; namely, that part which is considerably *elevated above the surface*.

Q. What matter is usually EXPELLED from the craters of volcanoes?

A. They send up *boiling streams of lava:* floods of *hot mud*, and showers of *ashes* and *cinders*.

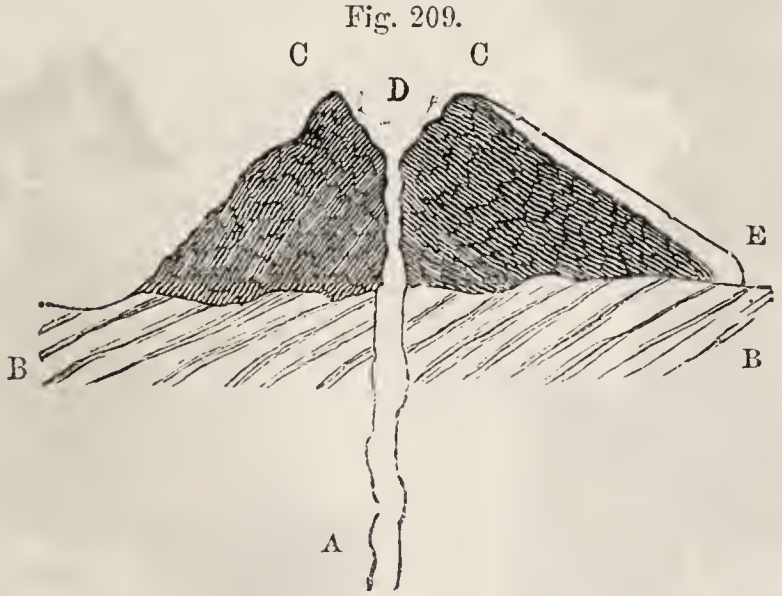
Q. Do geologists make any DISTINCTION between the characteristics of these craters?

A. Yes. Some are called *craters of eruption*, others *craters of elevation*.

Q. What is meant by a CRATER of ERUPTION?

A. A crater of eruption is one *formed by the masses of boiling lava expelled from the earth* through the fissure, vent, or chimney.

Fig. 209.

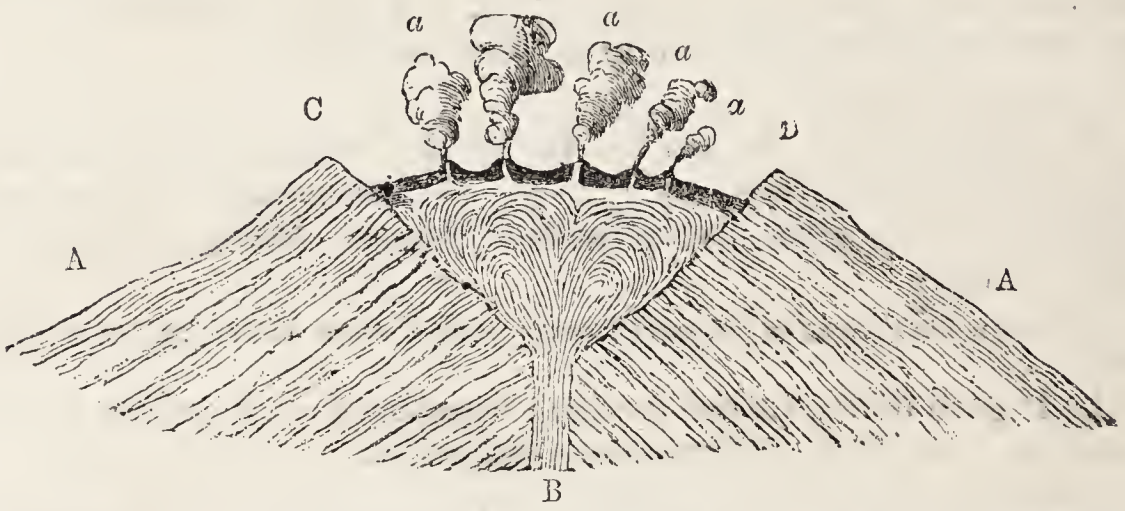


In the above diagram we have a representation of a crater of eruption. A is the fissure, or vent, produced by the internal heat of the earth. B B is the portion of the earth's crust through which it has penetrated. C C are masses of cinders and ashes, which have settled on the surface of the rock B B. D is the funnel-shaped crater. E is a stream of lava flowing over the cinders.

Q. What is meant by a CRATER of ELEVATION?

A. These craters are formed by the rupture of the *flat strata of the earth's crust.* The beds of strata are tilted up and thrown into highly inclined planes.

Fig. 210.



Here we have the representation of a crater of elevation. A A are rocks, which were originally horizontal, but which have been tilted up and snapped asunder by the force of melted matter, at B. The melted matter is not sufficient in quantity to flow over the edges of the crater C D; nor is the expansive power below strong enough to hurl it into the air: therefore it boils in the crater. Its surface is covered with a thin crust; and the volcanic materials escape only at the vents *a, a, a, a.*

Q. Has a crater only ONE VENT?

A. In the crater of a volcano, and on the sides of a volcanic mountain, there are generally a great number of smaller vents, emitting *water and gas.* Besides these, vents are sometimes formed by the fall of *scoriæ or ashes.*

Fig. 211.

Fig. 212.

In the above figures are seen a conical vent, formed by the fall of cinders on Vesuvius (*fig.* 211); and the structure and appearance of a conical vent after volcanic action has ceased (*fig.* 212).

Humboldt affirms that it may be considered as a pretty well established law of volcanoes, that those which have least elevation are characterised by the most unceasing activity. He proves this law by many examples, and explains it by the supposition, that a less internal force is sufficient to raise the molten masses to low than to high summits. He gives the following series of elevations of the craters of remarkable volcanoes :—

	Feet.
Stromboli	2,318
Guacamayo...	2,500
Vesuvius	3,876
Etna	10,870
Peak of Teneriffe	12,175
Cotopaxi	19,070

Now, of these, Stromboli has been in a state of activity from the Homeric age to the present ; so unceasing, that it has served, and still serves, all the purposes of a stupendous lighthouse to ships navigating that part of the Mediterranean. The entire island, situate off the north coast of Sicily, is of volcanic formation.—*Lardner.*

Of all the volcanoes which I have seen in either hemisphere, the cone-formed Cotopaxi is at once the most regular and the most picturesque. Before each great eruption the sudden fusion of the snow which habitually invests its vast cone announces the coming catastrophe, even before the appearance of smoke issuing from its lofty crater. The sides of the cone acquire a glowing temperature, and the mass of the mountain assumes an aspect of most awful and portentous blackness.—*Humboldt.*

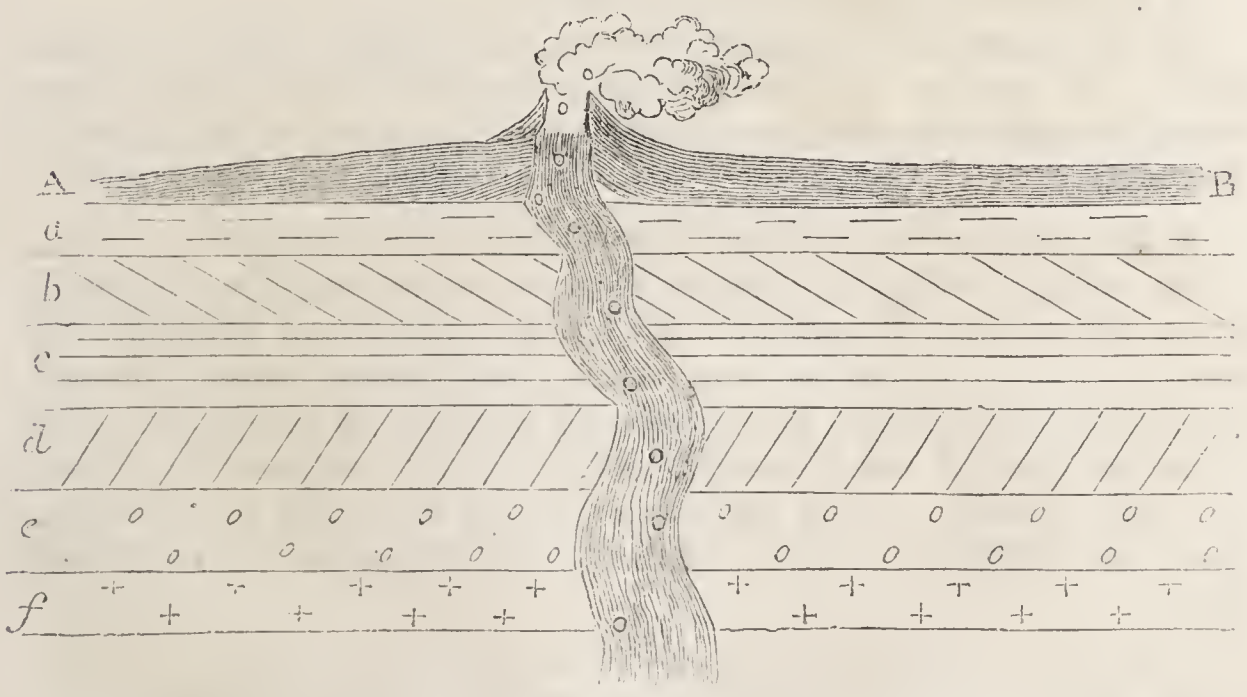
Q. Name the kind of matter thrown up by VOLCANIC ACTION ?

A. Among the materials thrown up by volcanoes we may mention *gases*, *watery vapour*, *lava*, *minerals*, *scoriæ*, *ashes*, *sand*, *water*, and *mud*.

Q. Are not STONES thrown up by volcanoes ?

A. Yes. The vent of the volcano passing through various strata *wears away fragments* from the sides of the rock, which are ultimately ejected at the cone. (*See fig.* 213.)

Fig. 213.



In the above diagram is seen how the vent of a crater passes through various beds of rock, such as *a*, *b*, *c*, *d*, *e*, *f*, some of which are fossiliferous, and others are of the more ancient class. The upper stratum, A B, is formed by the ejected matter which has been thrown up on all sides from the volcano.

Q. What is LAVA?

A. Lava is a name given to any *mineral matter melted in a volcano* and *ejected from the crater.*

When the melted lava cools it receives fresh names, and is known as scoriæ, cinders, pumice, basalt, trachyte, &c.

Q. What is SCORIÆ?

A. Scoriæ, or cinders, is the term applied to the *refuse* or *slag* of lava. Whether lava flows like a stream, or is thrown into the air like a fountain, it cracks, and becomes porous as soon as it is acted on by the *air.* The fragments, according to the effect of the air, assume a cellular appearance, that is to say, they are full of *little round holes*, as is seen in any piece of common *pumice stone.*

Q. Is it not recorded that, at the destruction of Pompeii, in the great eruption of Vesuvius, showers of ASHES DARKENED the air?

A. Yes. Volcanoes in eruption discharge immense quantities of *dry, hot ashes*, sometimes like impalpable powder, but very heavy as a mass.

Q. Do not some volcanoes EJECT WATER?

A. Nearly all the vapour discharged by volcanoes is that of *water.* It is this vapour, when condensed by cold air, that forms the springs which are on the sides of volcanic mountains.

Q. Is MUD ejected by volcanoes?

A. Yes. This mud is called by the Italians *lava d'aqua;* and some geologists are of opinion that by this *boiling mud Pompeii was destroyed.*

Q. Are volcanoes IN GENERAL NEAR to the sea?

A. In nearly all instances volcanoes are *situate near the ocean;* and in the opinion of some geologists eruptions are caused by water being brought into contact with the heated material in the bowels of the earth.

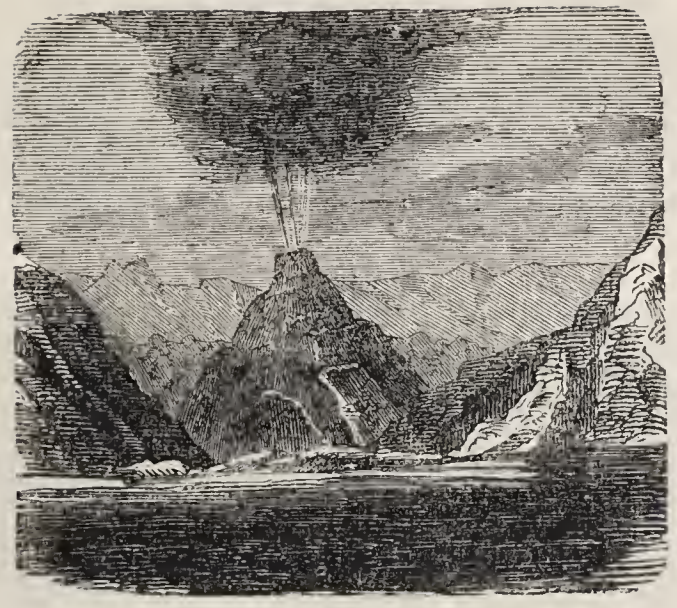
Q. How can the ACCESS of WATER be EFFECTUAL in producing ERUPTIONS?

A. Water coming in contact with *heated materials* far in the interior of the earth is changed into *steam.* The steam *suddenly rises, bursts open large fissures*, and causes *earthquakes*, which generally precede an eruption. The increasing pressure of steam will at last force the glowing mass upwards, with the solid materials that cover it, until it finds vent at some opening, as the crater of a volcano, and an eruption of lava, cinders, and fragments of rock takes place.

Q. Are volcanoes, for the most part, distinguished by a PECULIAR FORM?

A. They are generally *conical*, being in fact *gigantic air* or *steam vesicles*, which have been upheaved from below, and finally elongated to an apex, at the termination of which the steam or gas broke through. (*See fig.* 214.)

Fig. 214.



Q. How MANY volcanoes are there known at the present time?

A. Above *three hundred;* of these one hundred and fourteen are on the American continent or the adjacent islands.

Q. Are volcanoes situated chiefly on the MAIN LAND, or on ISLANDS?

A. In Europe and Asia they are, for the most part, on islands; in America they are chiefly on the main land.

The following is the volcanic distribution :—

Europe—On the continent	4	Total	24
,, On islands	20		
Asia—On the continent	17	Total	46
,, On islands	29		
Africa—On the continent	2	Total	11
,, On islands	9		
America—On the continent ...	86	Total	114
,, On islands	28		
Polynesian islands	108	Total	108
		Total known...	303

Q. What is KNOWN respecting MUD VOLCANOES?

A. That they *exist in different parts* of the world; are supposed to *originate with earthquakes;* that their *rise* is accompanied with *noises resembling the discharge of artillery*, and *with jets of flame.*

Q. Describe ONE OF THESE volcanoes?

A. The mud volcano of *Jokmali*, in the Caspian Sea, was *formed November* 27, 1827. *Flames sprung up from the sea, and blazed to a great height.* This lasted for about three hours. After this, for a *whole day and night*, it continued to burn about three feet above the newly-formed crater, from which great quantities of *mud were ejected.*

Humboldt describes a real mud volcano, near Carthagena, New Grenada, South America. There, in the midst of a thicket of palms, is a marshy ground, called Los Volcancitos. The tradition of the inhabitants is, that this ground was once all in flames, but that the fire had been extinguished through the good offices of a priest. Since then the fire volcano, so the people say, has become a watery one. The volcancitos are about fifteen or twenty in number, stand in cones, from nineteen to twenty-five feet high, and measure round their bases from seventy-five to eighty-five feet each. On the top of each

of these volcancitos is an aperture, or depression, from fifteen to thirty inches in diameter, and filled with water, through which air-bubbles are constantly escaping. In other parts of the ground there are apertures for such escapes of air, but which are not surrounded by cones. The cones have, no doubt, been raised by the clayey mud contained in the fluids; and the dull sound which precedes the boiling of the water in the cone indicates that the ground is hollow. It seems that each crater receives its supply of air and gas from separate channels. These little craters are filled with water even in the driest seasons. The temperature of the water is not higher than that of the atmosphere.

Fig. 215.

MUD VOLCANOES IN NEW GRENADA.

Q. Are HOT WELLS, or THERMAL SPRINGS, connected with volcanic action?

A. Of this there can be *little doubt*. It is evident that such springs are of a *mixed character*, partly *igneous* (*burning*), partly *aqueous* (*watery*).

Q. Are mineral springs USEFUL?

A. All mineral springs *contribute essentially to the benefit of animal* and *vegetable life*.

Q. How do geologists ACCOUNT for THERMAL, OR HOT SPRINGS?

A. Sometimes on the *theory* that the water *rises from a great depth*, at which the rocks are *intensely heated*. Sometimes on the supposition that the *internal heat of the earth* is forced upwards through fissures till it meets with water, to which it communicates heat. It appears, indeed, most probable that these springs *do* receive their heat from the interior of the earth.

Q. Do these thermal springs rise only from ONE KIND of rock?

A. No. They rise in *all kinds of places*, and from almost *all kinds of rocks*.

Q. What are the GEYSERS?

A. The Geysers are situated in *Iceland*, and throw up immense quantities of *steam* and *boiling water*. Within a circle of about *two miles*, *one hundred* of these Geysers are found. They rise in a thick bed of lava, probably derived from Mount Hecla, which is thirty miles distant.

Fig. 216.

THE GEYSER IN ICELAND.

In the above engraving we have a representation of what is called the Great Geyser. It rises out of a spacious basin, which surrounds a vent or a well. The basin consists of a mound, which has been formed round the well by flinty matter which has fallen from the spray of the water, and which has settled in a circular incrustation. The diameter of the whole basin is about fifty feet. In the centre is the well, shaft, or pipe, which goes some twenty-seven feet deep. At intervals this basin is quite empty, but usually it is filled with water, which continues to boil like water in a kettle over a fire.

Q. What are EARTHQUAKES?

A. The earthquake consists essentially of *movements of the earth's crust* or surface in the form of waves or undulations, which travel with great rapidity in all directions from the centre of the disturbance, that is to say, the place where the cause of the earthquake is situated

Q. What is supposed to be the CAUSE of EARTHQUAKES?

A. The *same agency exhibited in volcanic action—internal heat*—is undoubtedly the cause of earthquake phenomena. The cooling of the strata may cause contraction and movement of the earth's crust, or the pressure of gases generated by heat may cause violent movements and undulations of the strata.

Q. What is the INFLUENCE of earthquakes in changing the surface of the earth?

A. Earthquakes produce innumerable changes in the surface of the globe. Old lakes disappear, new lakes are formed; old islands are swallowed by the sea, new islands rise from its depths; portions of land are depressed, and others elevated; the relative positions of sea and land are changed; landslips occur on the sides of mountains; and rivers change their courses.

Q. What is the ACTION of an earthquake?

A. The action of an earthquake is *threefold.* It is *vertical*, and rises from the interior of the earth to the surface; it is *horizontal*, and follows the course of certain rocks or strata; it is *circular*, and appears to go round certain points in its course.

Q. What EFFECTS are produced by the VERTICAL ACTION of an earthquake?

A. It causes *cracks* and *fissures* in the *outer crust of the earth;* portions of the earth *slip down*, and are said to be swallowed up.

Q. What are the EFFECTS of the HORIZONTAL ACTION of an earthquake?

A. It causes *motions in the earth* similar to that observed in the waves of the sea. They proceed in one direction, and when they encounter *no resistance*, are not considered dangerous. If, however, the course of this vibrating movement be checked by coming into contact with other vibrating waves, the result of earthquake action, the effects are most frightful.

Q. What are the EFFECTS of the CIRCULAR MOVEMENT of earthquakes?

A. What is meant by the circular movement is, that the earthquake power *moves in a circle, large or small.* Thus the great earthquake which destroyed *Lisbon* was felt in Spain, in North America, in the Alps, in Thuringia, in the North of Germany, in Sweden, in Loch Lomond in Scotland, in the Great Lakes of Canada, and in the West Indies.

Q. Mention some instances of the SUBSIDENCE OF LAND by earthquakes.

A. In 1692 *Jamaica* was shaken by an earthquake. At *Port Royal* several large storehouses sunk below the level of the harbour, and some of them were forty-eight feet under water. A large tract of land and the town also sunk in less than a minute, and settled at the bottom of the sea.

Q. Has any STRIKING INSTANCE of the ELEVATION of land by the agency of an earthquake occurred within a RECENT period?

A. In 1822, an earthquake occurred in Chili, South America, which *permanently elevated a line of coast over an area of about one*

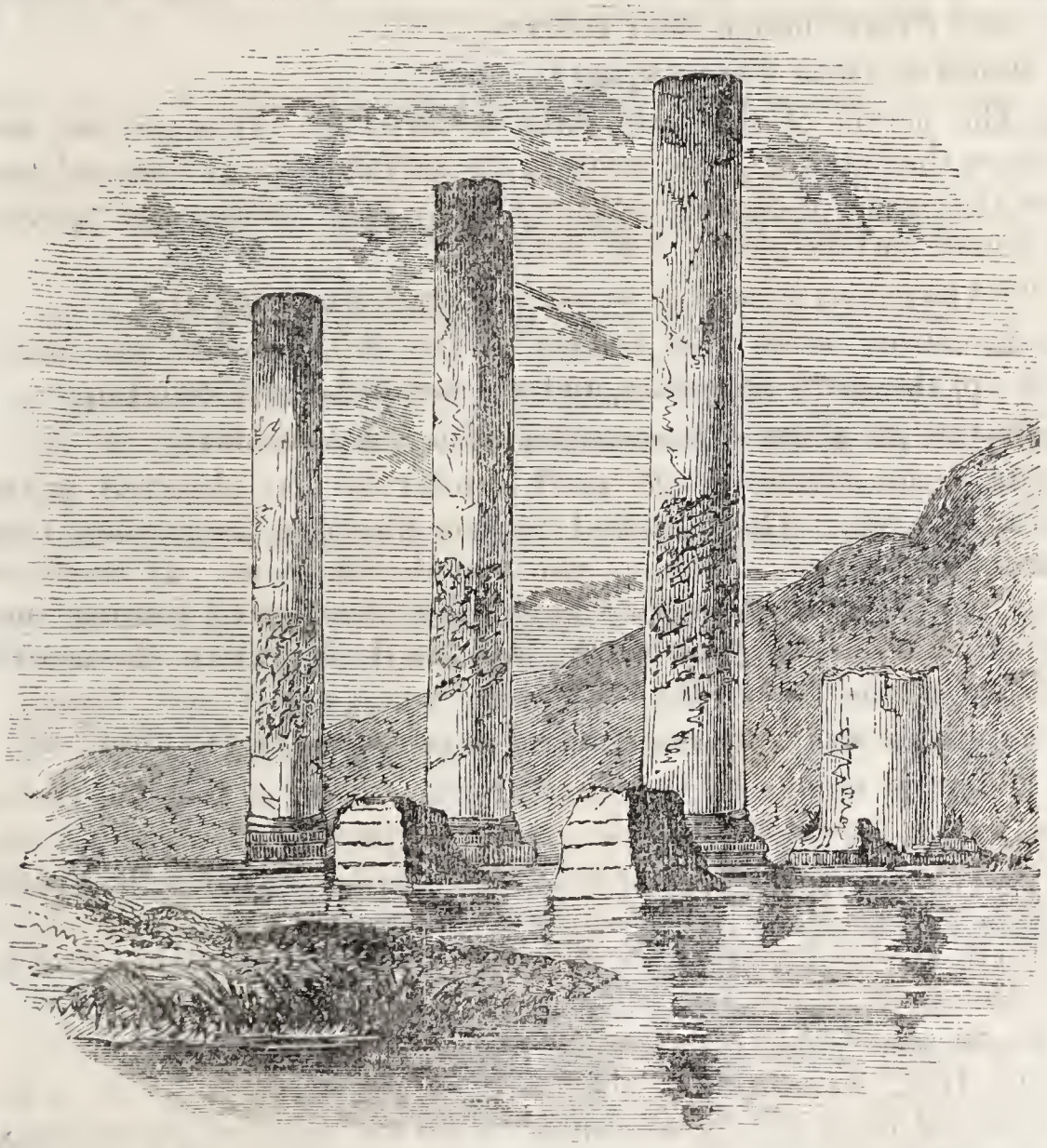
hundred thousand square miles—a territory equal in extent to half the country of France.

Some geologists suppose that the whole country, from the foot of the Andes to a great distance under the sea, was thus elevated, for the greatest rise was at the distance of two miles inland from the shore. On the coast the rise was two or four feet; but a mile inland it was six or seven feet. This elevation has been disputed by several naturalists; but it has been verified by the German travellers, Dr. Meyen and M. Freyer, and our own Darwin.

Q. What is the MOST REMARKABLE INSTANCE of these phenomena on land?

A. Some very remarkable phenomena of this description have taken place in the *Bay of Baiæ*, to the north of Naples.

Fig. 217.



The above illustration shows the remains of a temple situated close to the sea shore, at Puzzuoli, in the bay of Baiæ. It is known as the temple of Serápis. The roof of the building was supported by forty-six pillars—twenty-four of granite, and twenty-two of marble. Of these marble columns three only remain; they are about forty-two feet high. The surface of these columns is uninjured to the distance of twelve feet from the pedestal. Then a series of holes, or perforations, are seen in the marble, forming a regular band round the column, to the distance of nine feet. The surface then continues smooth up to the summit. The upper edge of the perforated base is now upwards of twenty-three

feet above the sea level. This curious fact illustrates the effects of the elevation and subsidence of land. There is no doubt that these perforations are the work of marine animals. Shells of a species of mussel have been found in the perforations. What does this fact teach? That at some distant period, but since the erection of the edifice, the coast on which the temple is built must have sunk below the sea level; that this depression must have continued for a considerable time—time enough, in fact, for the perforations to be made; that the coast must afterwards have been elevated; that both the depression and elevation of the land must have been so gradual as to permit the columns to maintain their erect position; and that the movements downward and up again must have been more than twenty feet. The time occupied by these changes has also to be borne in mind. They have taken place within less than eighteen hundred years. The Emperor Severus, who died A.D. 211, conferred on this building, then in a state of preservation, certain embellishments of marble. In A.D. 1198, a subsidence of the coast took place, and the temple sank with it. In 1530 it is well known that the whole of this coast was covered by the sea. In 1538, during an eruption of Vesuvius, the land on which the temple stood was elevated to the height of twenty feet. A gradual sinking of the coast is now said to be perceivable, and the base of the pillars is often covered with water.

Q. Does the elevation and subsidence of land ALWAYS DEPEND on the action of earthquakes?

A. No; land is sometimes *elevated*, and sometimes *subsides* by the expansion of subterraneous matter lying deep in the interior of the earth.

Q. Are such elevations and depressions observed in districts in which earthquakes are UNKNOWN?

A. They *are;* and the instances are numerous. Sea beaches are discovered at a *high elevation*, and forests are found to be *submerged.*

Q. Can you furnish an instance of this sort which has taken place at a comparatively RECENT period?

A. Yes. A large tract of land about *a thousand miles in length*, and *fifty or sixty in breadth*, situated on the northern shores of the *Baltic Sea*, has been *rising* for many years, and *is still rising.* It has already risen from *one hundred to two hundred feet* above the sea level.

Q. What do you know respecting SUBMARINE FORESTS?

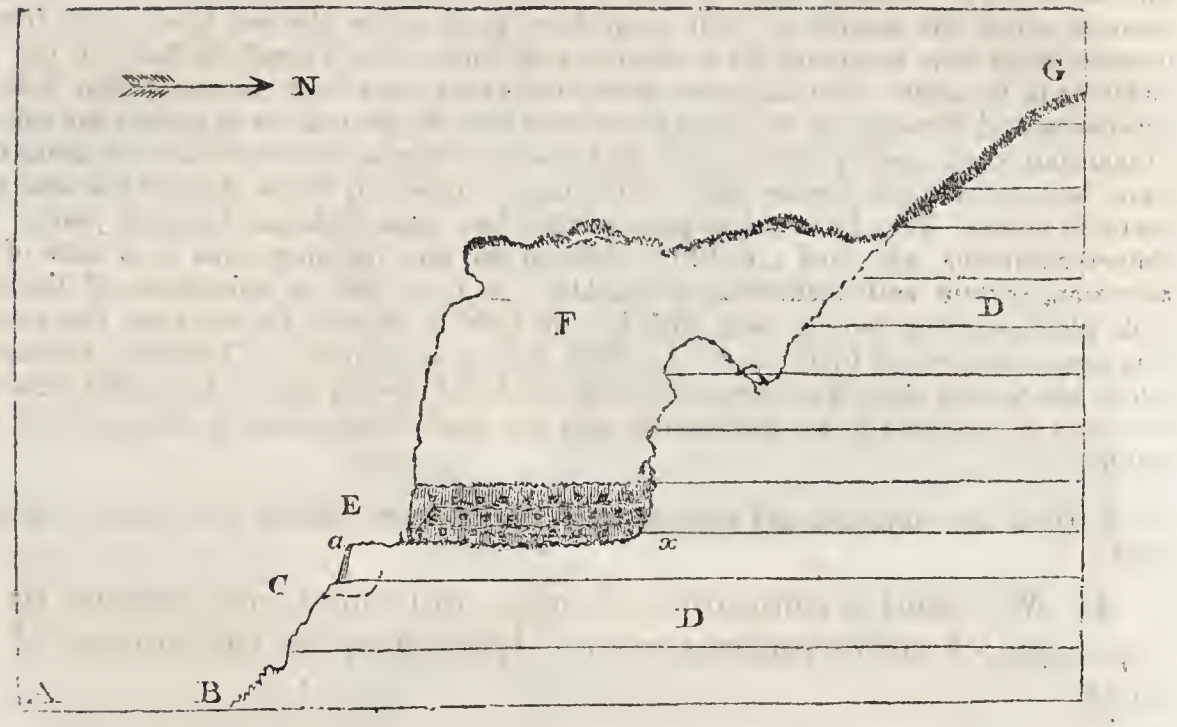
A. That on the shores of England, France, and North America, *swamps*, or *thickets*, or *forests* are found, in which *roots*, *trunks*, *branches*, and *leaves of birch*, *fir*, and *oak* are found intermixed with aquatic plants and shells; all of which evidence the fact that, at some distant period, these forests must have been *covered by the ocean.*

Q. Are not SEA BEACHES found at a high elevation?

A. Yes: in England as well as in many other parts of the globe. These beaches, now very high above the sea level, consist of *clays*, *muds*, *rounded pebbles*, and *shell deposits*—such as are found in the neighbourhood.

In the following diagram is shown the elevated strata and beach east of Kemptown, Brighton. A B is the present sea-level. C *x* is a terrace of chalk, part of the ancient chalk rock, D D. E is a bed of shingle, which, when the sea was at that level, formed the beach. F is a stratum, or bed of loam and chalk, in which the bones of ele-

Fig. 218.



phants have been discovered. Between the lower projection of the chalk D and the bed F, there is the stratum E. This, from its characteristics, proves to be an ancient sea-beach. From careful observation of these phenomena, we learn the following facts :— The entire chalk-rock D D was once the bottom of the ocean ; that it afterwards began to rise, and during its progress was worn away in parts by the sea-current, as seen along the line G *x a* C B. For ages the sea-level continued on the level of *a x*. The chalk-beds gradually arose, and the beach F was formed by the action of the waves on the chalk-cliffs. After the formation of the shingle-beach, the whole rock sank again to such a depth as to allow the deposit of the thick stratum F. Then the entire chalk rock, the elephant bed, and the ancient beach, began to rise, and continued to rise, till the sea stood at its present level, and formed the sea-beach as now seen.

Q. Does volcanic action take place UNDER THE OCEAN ?

A. It does; as rocks and sea-beach are elevated by the *fire under the earth's crust*, so this same action under the bed of the sea causes many singular phenomena.

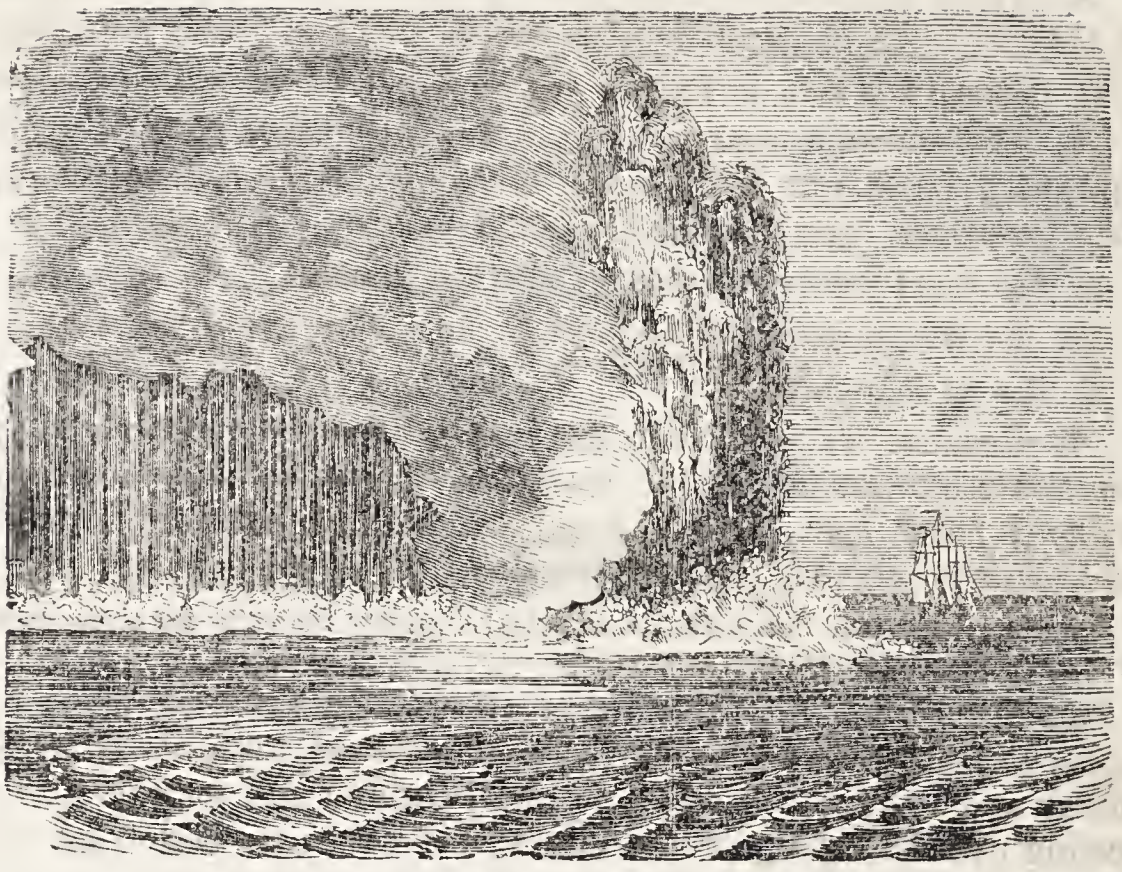
Q. How are these CHIEFLY DEVELOPED ?

A. By the *elevation of land from the depths of the sea, generally of a volcanic character.*

Q. Furnish an INSTANCE of this sort ?

A. A well-known instance is that of *St. Michael's*, in the Azores. In 1811, after the shock of an earthquake had been felt in the neighbourhood, *columns of ashes*, accompanied with *fire and smoke*, were seen to rise from the sea to the *height of several hundred feet.* At the close of the eruption an *island became visible*, and gradually rose to the height of *three hundred feet.* It had at one end a deep crater, out of which flames of fire were gushing under the water, and at the other end a summit in the form of a cone. The sea flowed into the crater, and the water there boiled as in a cauldron. After a few months the *island sank and entirely disappeared.*

Fig 219.

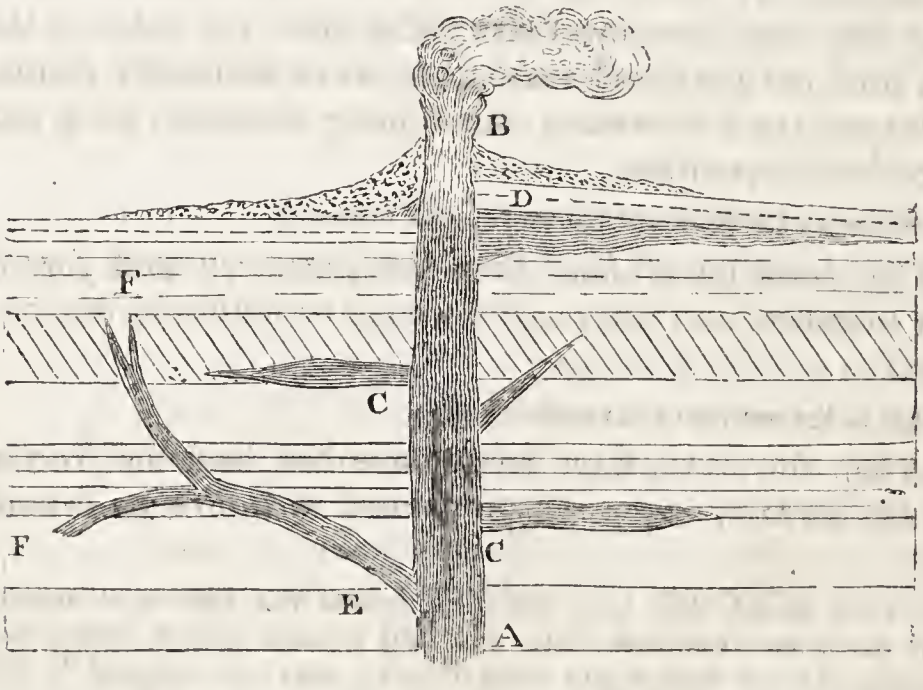


SUBMARINE ERUPTION, NEAR ST. MICHAEL'S, IN THE AZORES.

Q. What is meant by a VOLCANIC DYKE?

A. A *rock penetrating another rock* is called a dyke. It means generally *volcanic matter thrown into the fissures or crevices of other rocks.*

Fig. 220



This figure represents, A B, a column of liquid lava, passing through horizontal strata. Early in its rise it produces the fissure E F; at C it enters between two beds of strata; at D it divides the strata. This molten lava, afterwards cooling and hardening, produces those dykes, and other rocks, which are occasionally found in strata.

Q. How do you ACCOUNT for the FISSURES in the rocks?

A. These fissures may have been produced in the process of *cooling of the earth's crust*, or afterwards by the shock of an earthquake.

Q. How is it that LAVA, or VOLCANIC MATTER, could be thrown into these fissures?

A. The volcanic matter being in a *molten state*, and being forced upward, rushes into the fissures, in some cases produces them, and thus forms the mixture of rocks called *dykes*. (*See fig.* 220.)

Q. How have the MOUNTAINS upon the earth been FORMED?

A. By the *upheaval of portions of the solid crust of the earth.*

Q. How do we KNOW this?

A. Because we find that the *stratified rocks* of which they are sometimes composed, or the *stratified rocks* which are adjacent, are *changed from their original horizontal position*, and are now *tipped and tilted up*, so that in many instances the strata are nearly vertical.

Q. What appears to have been the IMMEDIATE AGENCY by which the strata have been broken up and thrown into INCLINED POSITIONS?

A. Masses of granite or other igneous rocks have been, by the agency of the *internal heat of the globe*, forced upwards from below, lifting and breaking through all the stratified and sedimentary rocks resting upon them.

Q. Are all the ranges of MOUNTAINS upon the earth of the SAME AGE?

A. Most of the great mountain ranges on the earth's surface have been elevated at *distinct and different periods.* Thus the Alps of Switzerland are of a comparatively recent origin, having been elevated during what is called the tertiary periods.

Q. How do we KNOW that the Alps were elevated during the tertiary periods?

A. Because we find that the *rocks* of this system have been elevated by the *same force*, and now exist upon the sides of these mountains in inclined positions. As they were evidently formed in horizontal layers, their elevation must have occurred at a period *subsequent* to their deposition.

Q. How are RAVINES, GORGES, and VALLEYS formed?

A. The *strata* have been doubtless *fractured* and *forced apart* in the first instance, and afterwards eroded or hollowed out by the action of water.

Q. What is the ORIGIN of CAVERNS?

A. When the strata have been fractured, and the *fracture does not come to the surface*, an *opening is formed* in the rocks, which we call a cavern.

Q. We have stated that each geological system has species of animals and plants peculiar to itself, and that these have gradually become extinct before the introduction and formation of a new system and series of rock: WHAT is supposed to have occasioned the extinction of WHOLE RACES of animals and plants in past ages?

A. The *changes in temperature*, and the *rapid mutations of land and water* were probably the principal agents of destruction.

Q. How could all the present races of animals and plants peculiar to the tropics be DESTROYED at ONCE, and the species rendered extinct?

A. By a *sudden change in the climate*, which should reduce the temperature to thirty-two degrees F. or less.

Q. Is there any REASON to BELIEVE that such CHANGES have taken place upon any portion of the earth's surface?

A. There is reason to believe that the climate of Siberia and Northern America was once *much warmer than it is at the present day.* In Siberia we find the bones of the *elephant*, the *lion*, the *tiger*, and other animals which can only live in tropical climates. Capt. Parry, at Melville's Island, within the Arctic Circle, found remains of plants similar to those now growing under the tropics.

Q. Have any species of animals become EXTINCT within the MEMORY of man?

A. *Several species* of animals, which have existed in considerable numbers within the memory of man, are now *utterly extinct*, and have *disappeared from the surface of the earth.*

Q. What are some EXAMPLES?

A. The bird called the *dodo* and the *apteryx*, the first a native of Mauritius, and the last of New Zealand, are both extinct. A species of *elk*, formerly common in Ireland, has disappeared.

Q. Do we know of any SPECIES of animals which are gradually DISAPPEARING?

A. Most *wild animals* which are hunted for their skins and furs are becoming more and more rare and uncommon. The *beaver* of North America and the *fur seal* of the Southern Pacific Ocean, once existing in great numbers, are now rarely met with.

CHAPTER LXV.

THE DILUVIAL AND TERTIARY SYSTEMS.

Q. In studying geology, is it NECESSARY to become acquainted with what is called the CLASSIFICATION of ROCKS?

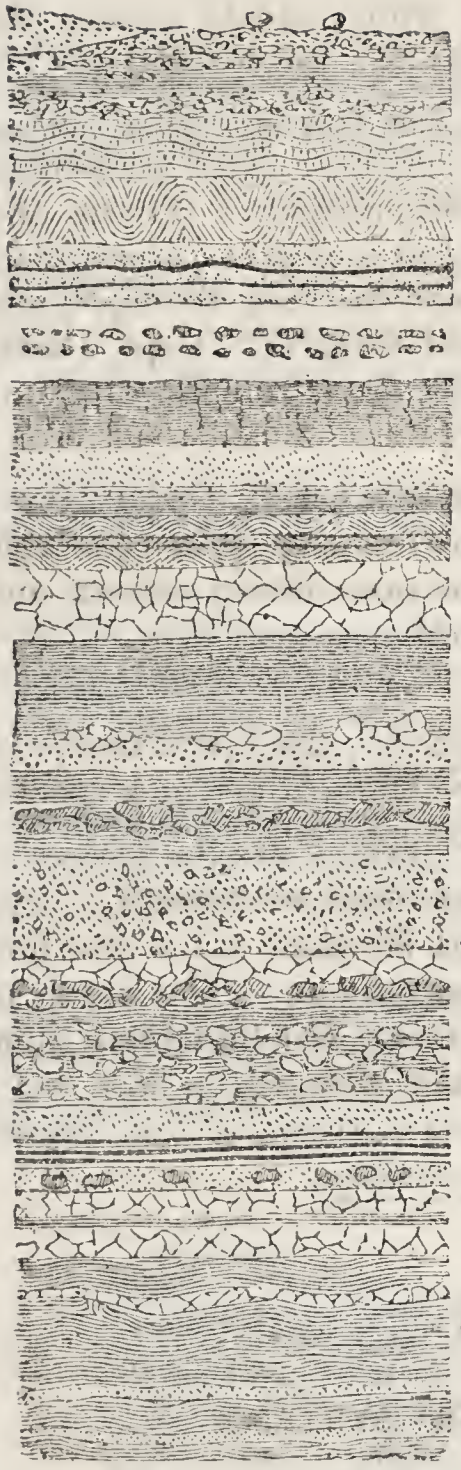
A. Yes; it is as essential to the geologist as learning the alphabet to one who wishes to be able to read.

The geological section on page 489 shows the position and order of the different rocks, from the surface to the granite, supposed to be below the strata marked V in the diagram.

Q. Does the WHOLE CRUST of the earth resemble, in its arrangement, the section shown in the diagram.

A. No; it is certainly possible that in some parts of the earth's surface, if a shaft were made, it would pass through the whole series, from A to V, but it is not at all probable.

Fig. 221



A. Alluvial Soil.
B. Erratic Blocks, and Till.
C. The Pleistocene.
D. The Pleiocene.
E. The Meiocene.
F. The Eocene.
G. The Chalk Formation.
H. The Quadersandstein.
I. The Neocomien.
J. The Wealden.
K. The Oolite.
L. The Lias.
M. The Keuper.
N. The Muschelkalk.
O. The Buntersandstein.
P. The Zechstein.
Q. New Red Sandstone, or Rothliegendes.
R. The Coal Measures.
S. The Mountain Limestone.
T. The Devonian, or Old Red Sandstone.
U. The Silurian.
V. The Cambrian.

AN IDEAL SECTION OF THE STRATIFIED ROCKS, IN THEIR VERTICAL ORDER OF POSITION.

Q. What, then, is the USE of this classification?

A. It shows us that the strata marked K or L will never be above the strata marked G, and that R will never be below V. In digging a shaft, any one of the rocks marked, or several of the rocks marked, might be missing, not occurring in that locality, never having been there upheaved or deposited; but their absence would not alter the accuracy of the classification, as, if they were there, they must occupy the positions marked. The entire series may never be found in one

district: but the members of any series that are found to occur, will follow the order of sequence.

Q. What NAME do we give to those great accumulations of SAND and COARSE GRAVEL which exist upon the surface of the earth, and, in geological order, are next beneath alluvial deposits?

A. *Diluvium* or *drift.* They are considered by many geologists to constitute the upper member of the tertiary system.

Q. What is the GEOGRAPHICAL RANGE of the drift?

A. In America it is found from *Nova Scotia* nearly to the *Rocky Mountains*, and extending as far *south as Pennsylvania and the Ohio River.* It also exists in the *northern portions of Europe and Asia.*

Q. How is this accumulation of sand, gravel, and boulders supposed to have ORIGINATED?

A. It is supposed that during the epoch of the drift, the northern portions of the Eastern and Western continents were *submerged and swept by an ocean current.* Through the agency of this current and of icebergs, the rocks forming boulders were *torn from their original beds*, and the existing deposits of sand and gravel, formed by the wearing and denudation of the earth's surface, were produced.

Q. Do we find in these beds of sand and gravel any ANIMAL REMAINS?

A. The quantity of animal remains found in the drift is *immense.* The epoch immediately *preceding* the drift agency was the period of the *mammoth*, the *mastodon*, and other *huge ruminant animals*, which probably became extinct before the creation of man.

Q. What was the CHARACTER of the mastodon and the mammoth?

A. They were animals *allied to the elephant*, and *resembling* it in *form* and *structure*, but *larger.* Skeletons of the mastodon have been found in various localities in the northern portions of the United States, some of them in the most perfect condition.

Fig. 222.

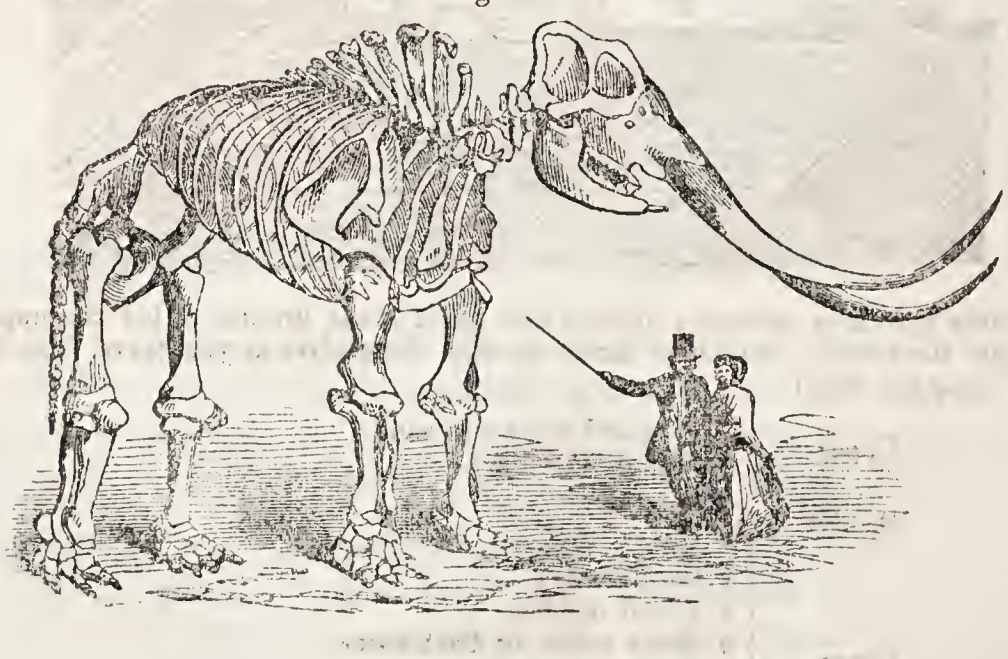


Fig. 222 represents the remains of a mastodon; one of the most perfect specimens ever discovered.

Q. WHERE are the deposits belonging to the tertiary system found?

A. The tertiary system, though not generally so continuous over large areas as the older formations, yet constitutes the *surface of a large part of Europe.* In the United States it occurs along the *seaboard from New Jersey to Louisiana.* It also covers large surfaces in *South America and Southern Asia.*

CHAPTER LXVI.

THE CHALK, THE OOLITE, AND THE NEW RED SANDSTONE.

Q. What SYSTEM of rocks succeeds the tertiary?

A. The *cretaceous* system, or the *chalk* formation.

Q. What is CHALK?

A. Chalk is a *carbonate of lime*, which appears to have accumulated in immense beds or layers at the bottom of a tranquil sea.

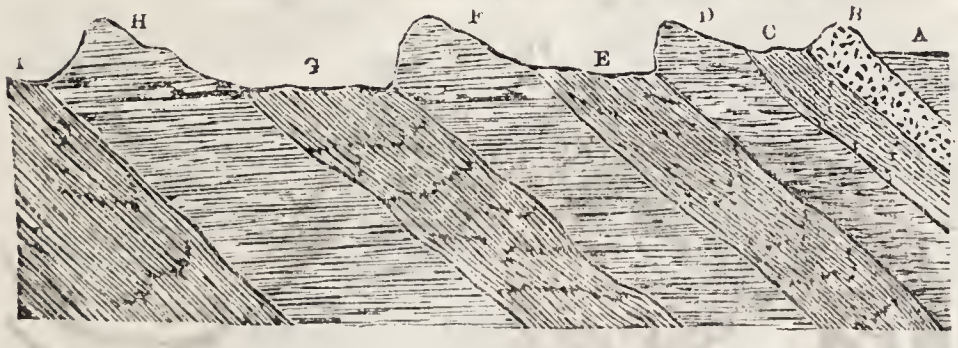
Q. What is the character of the FOSSILS of this system?

A. They are principally the *remains of marine animals* and *plants* in a beautiful state of preservation, such as corals, sponges, star-fishes, &c.

Q. Are the rocks constituting this system WHOLLY COMPOSED of chalk?

A. *No.* They consist of beds of clay, of greenish sand, and of limestone, with beds of pure chalk.

Fig. 223.



The oolitic system is generally divided into three great groups, called the upper, the middle, and the lower. All these strata develop themselves as you travel from London to Bath. (*See fig.* 223.)

Upper.	A	Portland stone and sand.
	B	Kimmeridge clay.
Middle.	C	Coral ray.
	D	Oxford clay.
Lower.	E	Cornbrush.
	F	Forest marble.
	G	Great oolite, or Bath stone.
	H	Stonesfield slate.
	I	Fuller's earth.
	J	Inferior oolite, or Cheltenham stone.

Q. From WHAT SOURCES are the flint-stones, from which gun-flints are manufactured, obtained?

A. From the *chalk formation;* the flint exists in the chalk in the form of rounded masses or nodules. When these nodules are broken by the hammer, they furnish the ordinary gun-flint.

Q. What GEOLOGICAL SYSTEM succeeds the chalk, or cretaceous system?

A. The *oolite;* made up, principally, of beds of clay and limestone.

Q. Why is this system called the OOLITE?

A. Because many of the limestones composing it have a curious structure, consisting of little *rounded particles*, resembling the *roe of a fish.* The word is derived from the Greek ωον, an egg, and λιθος, a stone. (*See fig.* 223.)

Q. What remarkable FOSSILS occur in this system?

A. The system was particularly characterised by the existence of *reptiles* of the *saurian* or *lizard order.* The most remarkable of these was the iguanodon, a lizard upwards of seventy feet in length, and proportionally large. It lived upon the land, and was herbivorous.

Fig. 224.

FOSSILS OF THE OOLITIC ROCKS

Q. What is an HERBIVOROUS animal?

A. One that *lives upon vegetable matter.*

Q. What TWO OTHER remarkable animals lived at this period?

A. The *ichthyosaurus* and the *plesiosaurus.*

Q. What was the CHARACTER of the ichthyosaurus?

A. It was a *fish-lizard*, somewhat resembling the crocodile. It was a *carnivorous animal* of immense power and rapacity, with *fins* like a fish, *paddles* like a turtle, and *eyes* of *unparalleled dimensions.*

Q. What was the PLESIOSAURUS?

A. The plesiosaurus had the *head* of a *lizard*, the *neck* of a *bird*, the *body* of a *fish*, and the *tail* of a *crocodile.* It appears to have lived in shallow waters, so that when moving at the bottom it could lift its head above the surface for air or in search of food.

Q. What was the CHARACTER of the vegetation of the oolitic period?

A. It must have resembled, in a striking manner, the *vegetation* which at the present day clothes the *islands of the South Pacific Ocean.*

Q. In what COUNTRIES is the oolite most extensively developed?

A. It is extensively developed in *England* and on the *continent* of *Europe.* It has been doubted whether this system has any representative in the United States.

Q. What SYSTEM immediately succeeds the oolitic?

A. The *new red sandstone*, often called the *triasic* or saliferous system.

Q. What are the CHARACTERISTICS of the rocks of this system?

A. They consist mainly of *layers* of *sandstones*, generally of a *red colour.*

Q. What valuable MINERAL occurs extensively in this system?

A. *Common salt;* salt beds and salt springs, with beds of gypsum, are so generally found in this system, that in Europe it is designated as the "saliferous (salt-bearing) system." The ores of copper are also found, to a considerable extent, in this formation.

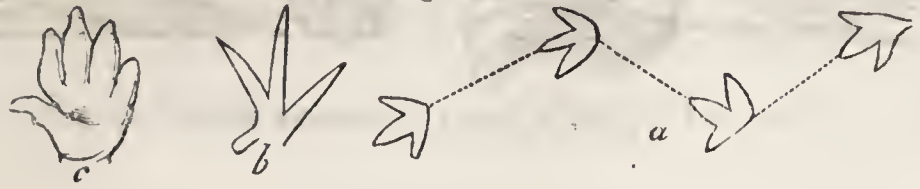
Q. Are FOSSILS ABUNDANT in this system?

A. They are *not;* the remains of *fishes* are frequently found, but few land animals, plants, or shells.

Q. What CURIOUS FOSSILS are found in the sandstones of this system in the valley of the Connecticut?

A. The *impressions of the feet of birds* and of some animals. Tracks, made by birds of more than thirty distinct species, have been distinguished. Fig. 225 represents the appearances of these impressions. Some of them, as seen at *c*, are impressions of the feet of reptiles, but the majority are undoubtedly the tracks of birds, as represented at *a* and *b.*

Fig. 225.



Q. How have these tracts been MADE and preserved?

A. The surface upon which the track was formed was originally a *soft mud.* After the impression was made, it *hardened into rock*, and thus a perfect *cast* or impression of the foot was preserved.

CHAPTER LXVII.

THE CARBONIFEROUS, OLD RED SANDSTONE, AND SILURIAN SYSTEMS.

Q. What SYSTEM in order succeeds the new red sandstone?

A. The *carboniferous* system, or *coal* formation.

Q. Does this system contain ALL the great deposits of coal found upon the surface of the earth?

A. It *does.*

Q. Why is not COAL found to any extent in OTHER rocks, or systems?

A. Because the *conditions* under which coal could be produced appear to have been *confined to one epoch of time*—namely, the period of the formation of the carboniferous rocks.

Q. What is COAL?

A. Coal is the *product of an accumulated vegetation* which flourished during the geological period which is represented by the carboniferous formation.

Q. How does the coal OCCUR in the earth?

A. In *strata*, varying from a few inches to several feet in thickness, enclosed between other strata of limestone, clay, or iron ore.

Q. How is the coal formation CLASSIFIED?

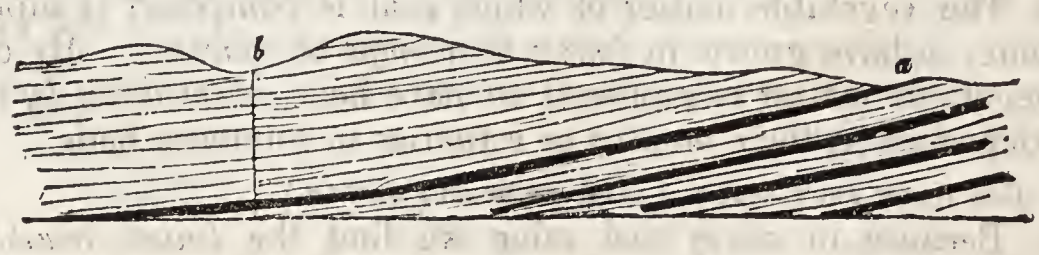
A. This series of rocks is *divided into three classes*,—

1. The *Coal Measure;*
2. The *Millstone Grit;* and
3. The *Mountain Limestone.*

Q. Describe those rocks which are specially called COAL MEASURES?

A. They consist of *deep beds of gritty sandstone, layers of soft clay, seams of coal, bands of clay, rocks containing ironstone*, and *sand rocks.* (*See fig.* 226.)

Fig. 226.

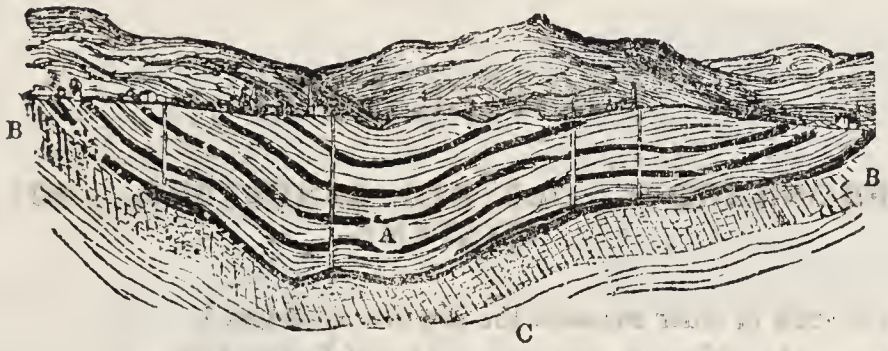


a, Entrance into the coal by adit, or level; *b*, entrance through the grits by a shaft.

Q. What is COAL?

A. Coal is a *pitchy mass of rotten vegetable matter*, mineralised. The coal beds are found in seams, separated from each other by layers of hardened clay and sand rock. The appearance of these coal seams is indicated in the accompanying engraving.

Fig. 227.



A, Seams of coal, shale, and sandstone; B, millstone grit; C, mountain limestone.

Q. What is the FLOOR, or the BED, on which a coal seam rests, called?

A. The *under clay*. It consists of a sandy or gritty *shale*, sometimes called *fire-clay*, on account of its capacity to be formed into bricks.

Q. What is the usual depth of these FLOORS, or BEDS?

A. They vary from a *few inches to ten feet*. Sometimes they are but very slightly coloured with coal matter, at others they are completely blackened with it.

Q. What is the LAYER which goes above the coal called?

A. The *roof*. This is generally of a slaty clay called *shale*. It abounds with *leaves*, *branches*, and fruits of plants.

Q. Does the VEGETABLE MATTER of which coal is formed ALWAYS take ONE FORM?

A. *No*. It is capable of *various modifications*, forming *peat*, *lignite*, *bituminous coal*, *anthracite*, *culm*, *steam coal*, *black lead*, and the *diamond*.

Q. What is MILLSTONE GRIT?

A. Millstone grit is *found beneath the sandstone*, *coal seams*, and *shales* of the coal measure; it is formed of *thick layers* of sandstones.

Q. What is the MOUNTAIN LIMESTONE?

A. It is the *basis* of the *coal formation*, and lies between the coal beds and the more ancient rocks—the old red sandstone.

Q. In what MANNER is it supposed that the great accumulation of vegetable material of which coal is formed took place?

A. The vegetable matter of which coal is composed is supposed, by some, to have grown in *immense swamps* or *marshes*. By others, the vegetable matter is supposed to have been *swept down by rivers*, and deposited at their mouths or estuaries in immense beds.

Q. How do we KNOW that coal is all VEGETABLE MATTER?

A. Because in every coal mine we find the *leaves*, *trunks*, and *fruits of trees* in immense numbers, many of them in a most *perfect*

state of preservation; so much so, that the botany of the coal period can be studied with nearly as great ease and facility as the botany of any given section of the present surface of the earth.

Q. What is the APPEARANCE of coal when examined under the microscope?

A. When coal has not been too much changed by heat or pressure, a thin layer exhibits all the *ducts and vessels of the plant* to which it originally belonged.

Q. What was the CHARACTER of the vegetation of the coal period?

A. The vegetation of the coal period was of a *tropical character*, consisting of *ferns* that attained the size and dimensions of our largest trees, of *gigantic reeds and mosses*, and a variety of trees which have no representatives now living.

Q. What KINDS and FORMS of VEGETABLES are chiefly found in the coal beds?

A. The *varieties are very great*, and contain the fossils of six hundred and eighty-three specimens of plants; in the whole group of the coal formation the *ferns* are the only plants that resemble plants of the present day. Among these ferns are included the *embroidered fern*, the *nerved-leaf fern*, the *wedge-leaf fern*, the *fern stem*, and the *round leaf fern.*

Q. What is the SIGILLARIA?

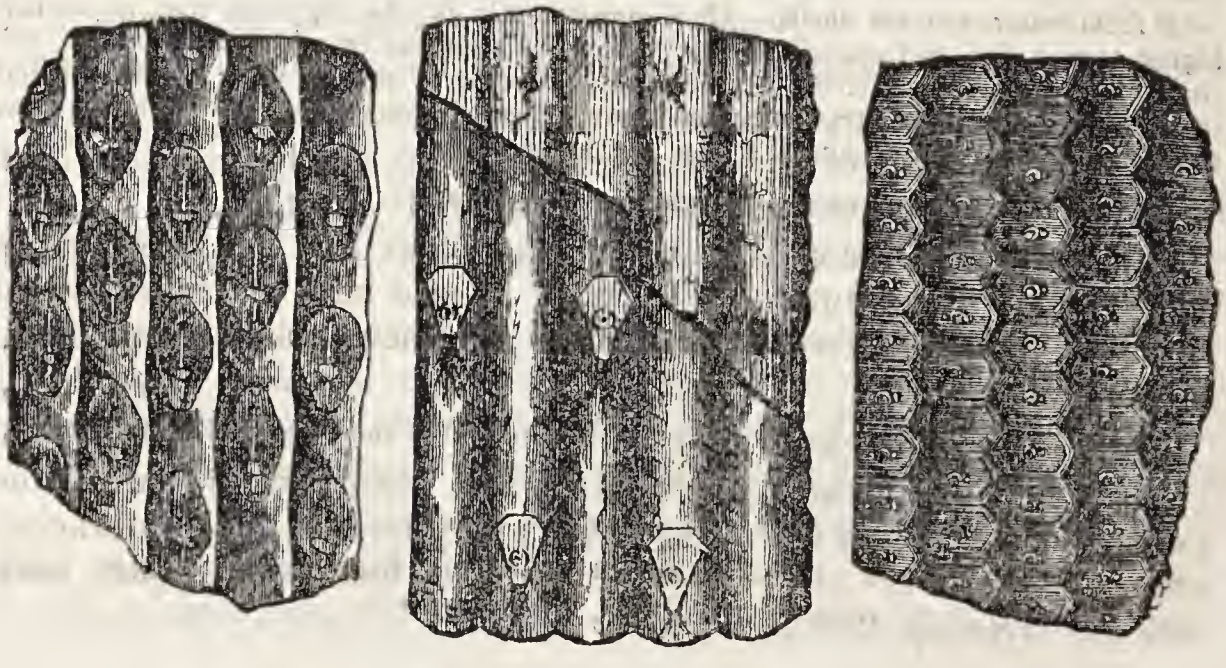
A. The sigillaria is one of the *most important plants* in the coal formation.

The sigillaria derives its name from the beautiful impressions which are made upon it, and which appear as well defined as though they had been produced by a sigillum—the Latin word for seal.

Q. What is the SIZE and APPEARANCE of this species of VEGETATION?

A. These sigillariæ grew in *lofty stems fifty* or *seventy feet high;* the surfaces of their trunks *fluted*, and generally without *branches.* They are now found in the form of long, flat, narrow slabs, their fluted surfaces bearing many curious impressions. (*See fig.* 228.)

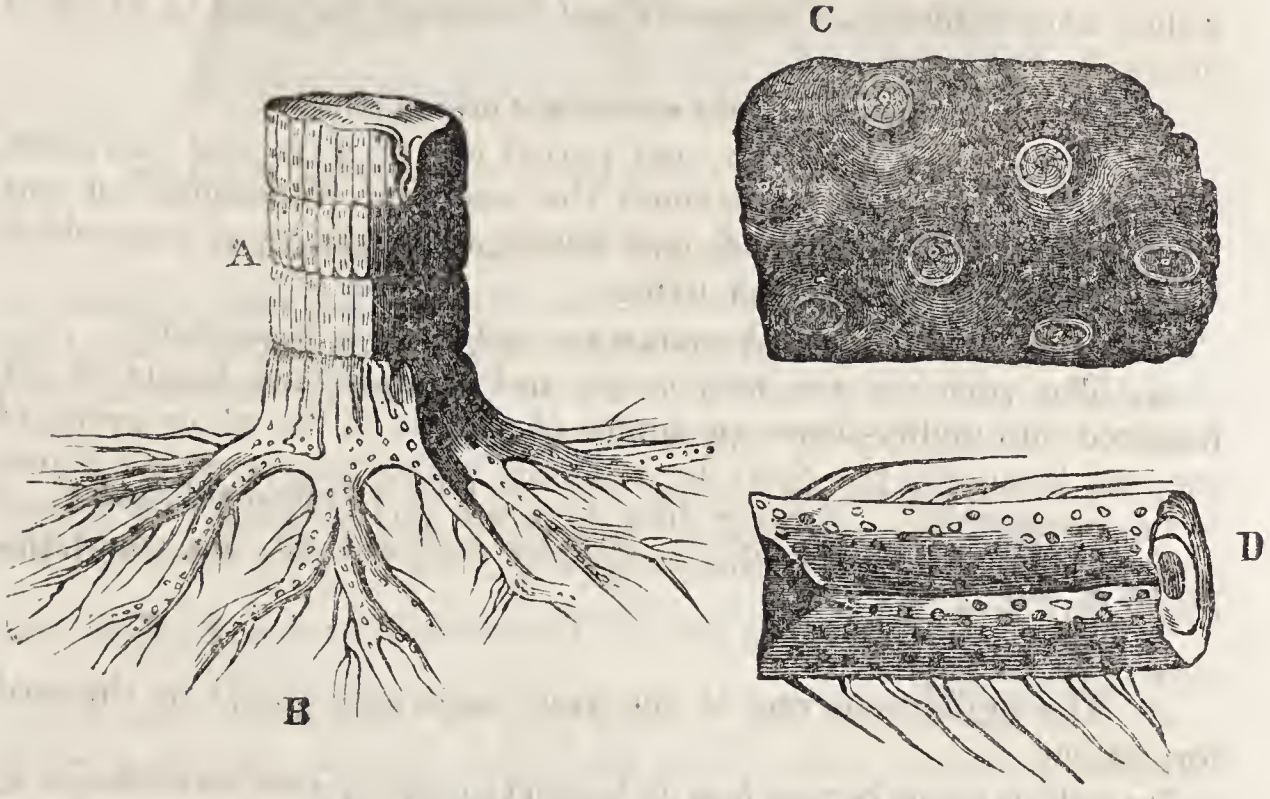
Fig. 228.



Q. What is meant by STIGMARIA ?

A. Stigmaria are *vegetable fossils*, found in the clay which forms the bed of the coal seam. They are found, in their natural form, branching out in all directions.

Fig. 229



FOSSIL VEGETABLES IN THE COAL FORMATIONS.

A, The trunk of a Sigillaria in contact with B, the Stigmaria, as its root. C, A fragment of Stigmaria, with its eyelet markings, magnified. D, A piece of Stigmaria ficoides.

Q. Are SHELLS, or FISHES, found in the coal formations ?

A. They *are.* Many remains of this description have been discovered.

The mountain limestone is rich in zoophytes, or animal plants, and in coral of several species. Three hundred different kinds of shells have been also discovered, including both fresh water and sea shells. Until very recently it was supposed that no animal higher than a fish had existed at the coal period ; neither frogs, tortoises, snakes, nor lizards having been discovered. In 1847 the skeletons of reptiles were, however, found in the coal works near Strasburg, and there appeared every reason for believing that these creatures properly belonged to the coal period.

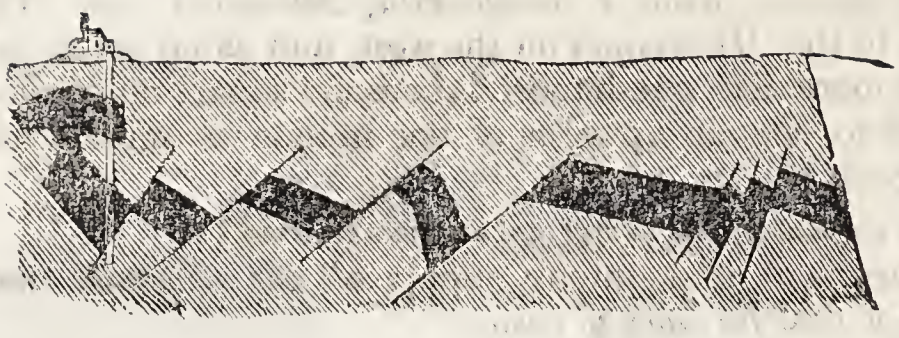
Q. How does BITUMINOUS coal DIFFER from ANTHRACITE ?

A. In anthracite coal the *volatile bituminous* part has been driven off by *heat.* The bituminous varieties of coal have *not been changed by heat*, and therefore *retain* most of their original vegetable constituents.

Q. Under what CONDITIONS do we find anthracite coal in the carboniferous formation ?

A. Where the strata are *broken up* and disturbed, indicating the action of *subterranean heat*, we generally find the coal to be anthracite; where the strata are *undisturbed*, the coal is, for the most part, bituminous. (*See fig.* 230.)

Fig. 230



VARIOUS DISLOCATIONS OF A COAL-BED AT VIEILLE-POMPE, IN FRANCE.

Q. How is this ILLUSTRATED in the great coal-fields of Pennsylvania?

A. The Eastern Pennsylvania coal-fields, which are adjacent to the line along which the Appalachian chain of mountains have been elevated, furnish only *anthracite*, but in Western Pennsylvania, away from the mountains, the coal is *bituminous*.

Q. What is the GENERAL ARRANGEMENT of the coal-fields in England and Wales?

A. 1. The *Great Northern District* includes all the coal-fields north of the Trent;

2. The *Central Districts* include Leicester, Warwick, Stafford, and Shropshire; and

3. The *Western Districts*, which may be subdivided into *North-Western*, including North Wales, and *South-Western*, including South Wales, Gloucestershire, and Somersetshire.

There are 3,000 coal mines in Great Britain, which employ nearly 250,000 men, women, and boys, underground and above. The capital invested in working stock, tramways, shafts, and harbours, altogether exceeds £30,000,000 in value. The "get of coals" amounts to about 34,000,000 tons annually, the estimated value of which, at the pit's mouth, is £10,000,000. One-third of this is worked from the Northern coal-field, in the counties of Northumberland and Durham, from whence, by the rivers Tyne, Wear, and Tees, the chief shipments of coals are made, both foreign and coastwise. The chief points of home consumption are in the iron works of Staffordshire, South Wales, and the West of Scotland; which, with the lesser works of North Wales, Shropshire, Yorkshire, and Derbyshire, consume nearly one-third of the whole. The Lancashire coal-field produces about 4,000,000 tons annually; Wigan, 2,000,000 tons annually; Bolton, 1,000,000 tons annually; St. Helens, 1,000,000 tons annually. The cost of "getting" the coals appears to average much the same in Lancashire as in Durham and Northumberland; the reason of the latter obtaining such a heavy preponderance in exporting appears to arise from the increased vigour with which the trade has been pushed there, and the increased facilities that have been created in railways, staiths, &c.; the operation of loading a vessel with coal at Newcastle, Sunderland, Shields, Hartlepool, Middlesbro', &c., being performed in about as many hours as it takes days for the same task in Liverpool.

Q. Is the carboniferous formation of GREAT EXTENT?

A. It *is*. It exists in *all the great divisions of the earth*. Large deposits of coal occur in the United States, in Pennsylvania and the Valley of the Mississippi.

Q. What AMOUNT of coal is supposed to be ANNUALLY mined in EUROPE?

A. An amount exceeding *seven hundred millions* of hundredweight; of which England alone contributes four hundred and fifty, and Germany about forty millions.

Q. What is the EXTENT of the great American coal-field?

A. It extends from *Pennsylvania*, *Maryland*, and *Virginia* on the east, to the *Mississippi* on the west, and as far south as *Alabama*. It covers more than one hundred thousand square miles, and has been estimated to contain upwards of one million of million tons of bituminous coal.

Q. May the coal deposits be regarded as INEXHAUSTIBLE?

A. They will undoubtedly supply *all the demands* that may be created for coal *for ages to come*.

RELATIVE AMOUNTS OF PRODUCTION OF MINERAL COMBUSTIBLES IN THE SIX PRINCIPAL COAL-PRODUCING COUNTRIES OF THE WORLD.

	Tons.
Great Britain—Annual production	31,500,000
Belgium	4,960,077
France	4,141,617
United States of America:—	
Anthracite	2,650,000
Bituminous	1,750,000
Prussia	3,500,000
Austria	700,000

THE SUPERFICIAL COAL AREAS OF VARIOUS COUNTRIES.

(From Taylor's "Statistics of Coal.")

	Square Miles.
United States of America:—	
Bituminous coal area	133,132
Anthracite coal of Pennsylvania	437
British America:—	
Bituminous coal area	18,000
France, ditto	1,719
Belgium, ditto	518
Spain, ditto	3,408
Great Britain and Ireland:—	
Anthracite and culm coal area	3,720
Bituminous	8,139

Q. What SYSTEM SUCCEEDS the carboniferous?

A. The *old red sandstone*, also called the *Devonian* system.

Q. What is the CHARACTER of this system?

A. This formation consists almost entirely of sandstones of a red or gray colour. It is extensively developed in England, and to some extent in the United States. The Catskill Mountains are made up of rocks belonging to this system.

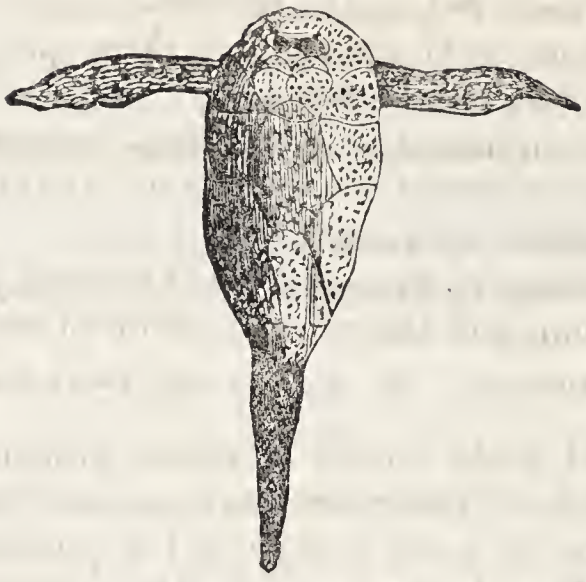
Q. What are the PECULIAR FOSSILS of the old red sandstone?

A. The fossils of this system are a *few shells*, a *small number* of *vegetable species*, and in some localities the remains of *fishes* occur in great abundance.

Q. What is the DISTINGUISHING CHARACTERISTIC of the FISHES of this system?

A. The fishes of this system have a skeleton composed of *cartilage* (gristle) covered with *plates of bone*. The jaws, consisting of solid bone, were not covered with integuments, and the exterior bony covering seems to have been the true skeleton, as is, in part, the case with the tortoise. (*See fig.* 231.)

Fig. 231.



THE PTERUPTHYS, OR WINGED FISH, UPPER SIDE.

Q. What SYSTEM SUCCEEDS the old red sandstone?

A. The *silurian*, divided into the upper and lower silurian formations.

Q. Is this system EXTENSIVELY DEVELOPED?

A. The silurian system of rocks covers a *greater portion of the earth's surface*, and is better known and studied, *than any of the other geological formations.*

Q. WHERE do the silurian rocks occur in the United States?

A. The silurian rocks occupy a large portion of the *territory west of* the *Alleghany Mountains*, from Canada, through New York and the other States to Alabama, and extending westward far beyond the Mississippi. Most of the rocks in the State of New York belong to the silurian system.

Q. What is the CHARACTER of the FOSSILS of this system?

A. The fossils of the silurian rocks are *very numerous*, but consist mostly of *the lower forms of animal life*, of marine origin. They are shells, corals, and some articulata, as worms and crablike animals.

CHAPTER LXVIII.

ON THE PROGRESSIVE DEVELOPMENT OF ANIMAL LIFE UPON THE SURFACE OF THE EARTH.

Q. What FACT is revealed to us by the study and examination of the stratified rocks of our globe?

A. That as regards animal and vegetable life, there has been a *continuous* and *gradual progression* in the acts of creation, from the time when the first organised being was created up to the period of man's appearance upon the earth.

Q. Are there any MEANS by which the geologist can determine the antiquity of the earth, or the time which has elapsed since the sedimentary deposits COMMENCED ?

A. There are *no means* of determining these questions; yet a *very great degree of antiquity can be shown.*

Q. From WHENCE have the materials which compose the stratified rocks been OBTAINED ?

A. From the *destruction of the igneous* or *primitive rocks.*

Q. How was the destruction ACCOMPLISHED ?

A. In part, doubtless, by the *operation of volcanic forces*, but mainly by slow disintegration, and the eroding action of water.

Q. How does the EXISTENCE of the stratified rocks PROVE the great antiquity of the earth ?

A. The stratified rocks consist of *layers*, probably not averaging one tenth of an inch in thickness; and yet each layer is *distinct* in itself, in consequence of some change in the conditions under which it was deposited. The *time* required for these depositions must have been *very great*, as the thickness of the metamorphic and fossiliferous rocks is estimated to be at least eighty thousand feet.

Q. What does the EXAMINATION and study of the igneous rocks, constituting the foundation of the earth's crust, TEACH ?

A. That there was a *period* when *animal and vegetable life did not exist*, and the surface of the globe was *one homogeneous mass.*

Q. In what STRATA and SYSTEM do we find the first evidences of animal and vegetable life on the earth's surface ?

A. In the *oldest* and *lowest strata* of the *silurian* system.

Q. What is the CHARACTER of the fossils of these strata ?

A. The fossils of these strata consist of one or two species of worm-like animals, a few *shells* and *sea-weeds*, of the lowest orders of animal and vegetable life; these fossils are supposed to be the remains of the first organised structures that were created.

Q. As we ascend in the series of rocks, what is the CHARACTER of the fossils belonging to the strata of the MIDDLE SERIES of the silurian system ?

A. The *number and variety of shells increase; corals* and curious articulated and jointed animals called *crinoids* and *trilobites* make their appearance. The *remains of fishes* also have been found in these strata.

Q. What is the CHARACTER of the fossils of the upper silurian rocks ?

A. In these rocks *fossil shells* in immense numbers, exhibiting an almost infinite variety of form and structure, exist. *Fishes* appear in greater numbers during this epoch. *Corals* are abundant, and vegetable life has also expanded. All these forms, however, are of the lowest orders of organised existence.

It was once believed that animals were successively created in the order of their relative perfection, so that the most ancient formations contained only animals of the lowest grade, such as the polyps, and echinoderms, to which succeeded the mollusks ; then the articulated animals ; and last of all the *vertebratæ*. This theory is now, however, untenable, since fossils belonging to each of the four departments have been found in the fossiliferous rocks of every age.—*Agassiz.*

By this it is to be understood that the four orders of animal life have representative fossils in the rocks of the lower silurian formation. Whether they commenced their existence at a simultaneous period we have no evidence ; in the oldest strata of the low-

silurian formation they do not occur together. All the forms of animal and vegetable existence belonging to those older rocks are also exceedingly low in the scale of organisation, and during this whole period no air-breathing animals existed.

Q. What PROGRESSIVE DEVELOPMENT occurs in the next system of rocks—the old red sandstone?

A. The period represented by the strata of the system has been called the "*reign of fishes.*" In the silurian system fishes made their appearance during the formation of the lower strata, but were few in number and low in organisation. In the period of the old red sandstone, they existed in immense numbers, and possessed a highly organised structure.

Q. Did any LAND ANIMALS or PLANTS exist at this period?

A. We have *no evidence* that they did; the ocean probably covered the greatest portion of the earth's surface.

Q. What is the CHARACTER of the ORGANIC REMAINS found in the carboniferous rocks?

A. During the carboniferous period, *vegetable life* was developed in an *extraordinary manner*, and under a great variety of forms. Many of the plants of this period belonged to the class cryptogamia (plants that never flower); the great mass of the coal, however, appears to have been derived from the structure of endogenous plants, and from trees allied to the pine and fir.

It is exceedingly rare to find remains of plants or trees of high organisation allied to the oak, the elm, or maple during the carboniferous epoch.

Q. During what EPOCH do we FIRST find the remains of land animals?

A. In a few rare instances, indications of the existence of *land animals of low organisation* have been first observed in the rocks of the *carboniferous epoch.*

Q. Was the earth, at the period of the formation of the carboniferous rocks, in a FIT CONDITION for the HABITATION of MAN and LAND ANIMALS?

A. A large portion of the earth's surface at that period was undoubtedly but *little elevated above the surface of the water*, and was *low* and *swampy.* There is also reason to believe that the *atmosphere* was charged with *carbonic acid gas* to such an extent as to render it *irrespirable* by any of the higher orders of animals. Fig. 232 represents the fauna and flora of the carboniferous period.

Fig. 232.

Q. Does there appear to be STRIKING EVIDENCES of DESIGN in the extraordinary development of vegetation at this period?

A. The design of this abundant growth was *prospective.* The plants of the coal period were not fitted for the nourishment or support of animal life, but for *fuel;* and these remains have been stored up until the era of man, when this mighty supply of carbonaceous matter has become subservient to his happiness and necessities.

Fig. 233.

Fig. 233 represents the appearance of the fauna and flora of the oolitic period?

Q. What CHANGES in animal and vegetable forms take place in the three succeeding systems, the new red sandstone, the oolite, and the cretaceous?

A. In these three systems large *reptiles* prevail to an extraordinary degree; so much so, that the period has been designated as the "*reign of reptiles.*" *Birds* first appear in the *period of the new red sandstone.* Many land animals also for the first time came into existence, and vegetation was greatly modified, the peculiar plants of the coal period having become extinct, and exogenous trees having become more common.

Fig. 234.

Q. What are the CHARACTERISTIC FORMS of animal and vegetable life in the TERTIARY period?

A. During this period a condition of things prevailed not very

dissimilar to that of the present period. The huge reptiles of the former eras have disappeared, and have been succeeded by *gigantic land animals*—the *mastodon*, the *mammoths*, *elephants*, various species of the *rhinoceros*, &c.

A class of animals allied to the hippopotamus and the tapir, now extinct, existed also at this epoch. All the existing orders of animals, including the monkey family, were represented in this period. Figs. 234 and 235 represent the fauna and flora at the commencement and close of the tertiary period ?

Fig. 235

Q. Is there reason for believing that the CLIMATE of the globe during the tertiary period was WARMER than at the present ?

A. We find the remains of *tropical animals* and *plants* imbedded in strata of this period in *extreme northern countries*. Hence we infer that the climate of these countries was at that period of a tropical character.

Q. Why do we suppose that MAN did NOT EXIST at this period ?

A. Because although we find *remains of all the animals and plants* that then flourished, we have never met with the *bones of man or any of the works of his hands* in any of the rocks found during this period.

Q. WHEN did man make his appearance upon the earth ?

A. At the *termination of the tertiary period*, and after the formation of the drift or diluvium.

Q. What FAMILY of PLANTS appear to have come into existence contemporary with man ?

A. Geologists have never found any fossil remains of the plants belonging to the family of the *rose*, which includes not only many of the most beautiful flowers that are known, but also the *richest fruits*, as the *apple*, the *pear*, *peach*, *strawberry*, *cherry*, &c. Hence it is inferred that the introduction of this family was *coeval with*, *or subsequent to*, *the creation of man*, to whose comfort and happiness they seem especially designed by a wise Providence to contribute.

Q. Do beds of ROCK or EARTH exist, EXCLUSIVELY COMPOSED of the remains of MICROSCOPIC ANIMALS ?

A. There are *extensive beds of rock and earth wholly composed of the*

remains of minute animalculæ, called *infusoria*, the shells or coverings of which, being formed of silica, are nearly indestructible.

The rock, or stone, known as tripoli, or polishing slate, consists entirely of the remains of these animals, so minute that a cubic inch contains upwards of thirty-five thousand millions of individuals.

Fig. 236.

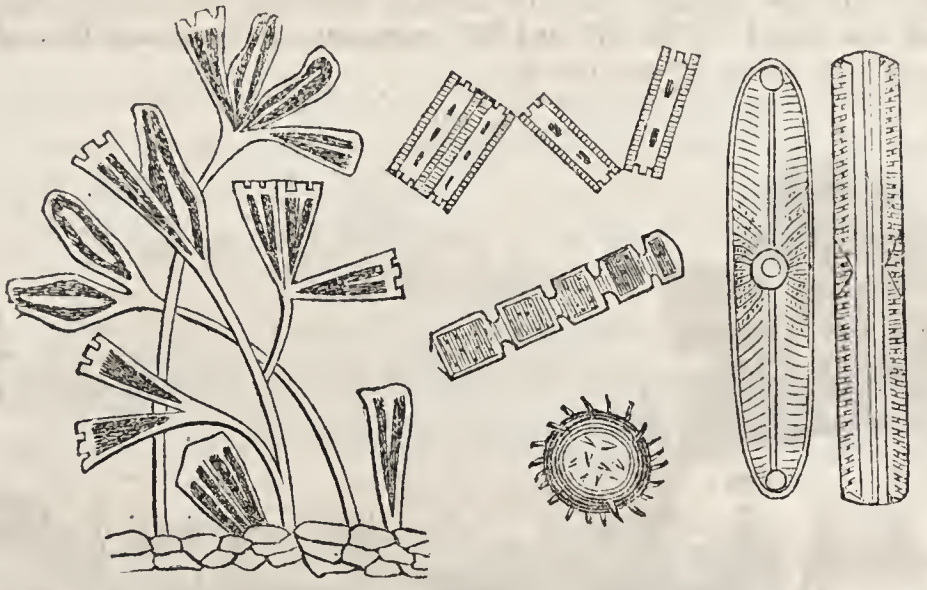


Fig. 236 represents the forms of these infusoria, as seen with the microscope.

Q. What does geology TEACH respecting man's POSITION upon the earth ?

A. It teaches us that his position is one *far in advance of all other and former creations.* It shows that since the work of creation commenced upon the earth, there has been a *progressive improvement* of its surface, all with a design of fitting it at last for the abode of the human race.

Q. Is it PROBABLE that any MATTER has been added to the bulk of the earth since its first creation ?

A. If we except the small masses, called meteorites, respecting whose origin we are ignorant, *no grain or matter* has been added to our planet since its creation, neither can *any be removed.*

CHAPTER LXIX.

ECONOMICAL GEOLOGY.

Q. If NO geological CHANGES had taken place, what would have been the PRESENT CONDITION of the earth's surface ?

A. It would have been *an almost uniform plain*, ill adapted for the abode of man.

Q. What RESULTS have been PRODUCED by the violent disruption, upheaval, and change of the earth's crust ?

A. The *division of the general surface* of the earth into *land* and *water*, as well as the diversified form of the land, the existence of

mountains and lowlands, and the consequent modifications of climate; the water-falls, river-courses, and the drainage of continents,—are all the results of upheavals of the earth's crust.

Q. Should we have known of the EXISTENCE of GRANITE if the strata had not been LIFTED UP?

A. We should *not*, as granite was formed *below* the sedimentary rocks, and covered by them to the thickness of many thousand feet.

Q. How have MINERAL VEINS, BEDS of MARBLE, SALT, &c., become ACCESSIBLE to us?

A. The *strata* containing these substances have been *forced up* towards the surface of the earth; whereas, if they had remained in their original position, it would have been necessary to have sought for them far beneath other overlying rocks.

Q. How do the ORES of different metals OCCUR in rocks?

A. They sometimes occur in *beds* or *layers*, as iron ore, sometimes in *veins*, and occasionally as *masses* of pure metal.

Q. What is a MINERAL VEIN?

A. A mineral vein is a *separation in the continuity of rocks of a limited width*, but extending indefinitely in *length and depth*, and filled to a greater or less extent with *metallic* or *mineral substances*, of a *different nature* from that of the rocks they traverse.

METALS.

Q. Are mineral veins confined to any PARTICULAR CLASSES of rocks?

A. They are *not* confined to any particular *epoch of formation*, nor to any *portions* of the earth's crust, although they are most frequent in beds that form mountain elevations, and in the oldest rocks.

The minerals are not distributed on the earth according to climate, like animals and vegetables; but, by the kindness of Providence, those which are most necessary to man are found in almost all countries; and others are more or less abundant according to their importance. It is remarkable, also, that the most barren portions of the earth are often most plentiful in mineral treasures.—*Hughes.*

Q. In some instances how does the vein or fissure in the rock appear to have been FILLED with METALLIC ORES?

A. The metallic substance oftentimes seems to have been *forced up* in a *melted state* from the interior of the earth, and, flowing into all the little fissures and cavities, to have hardened and crystallised. In such veins the *deeper* we penetrate into the crust of the earth the *richer* they become.

Q. Do veins or beds of metalliferous ore ever appear to have been formed by ELECTRO-CHEMICAL ACTION?

A. In certain cases the mineral and metallic particles appear to have been collected from the *adjacent rocks*, and deposited in a particular locality by the action of *electro-chemical forces*, in somewhat the same way as the metal is deposited at the *terminal pole of a galvanic battery* in the process of *electrotyping*.

Q. What is the ORDINARY COLOUR of METALS?

A. There is *little variety* in the colour of metals. Gold is the only *yellow* metal, copper and titanium are *reddish*, all the rest are *different shades of white.*

Q. What do you mean by DIFFERENT SHADES of WHITE?

A. *Variations* from the *pure dead white* of silver to the *bluish-gray* of lead.

Q. Which is the MOST PRECIOUS of all metals?

A. *Gold.*

Q. HOW and WHERE is it usually found?

A. It is usually found in *grains* or *gold-dust*, *in a pure state;* but nearly *three-fourths* of the gold in use is obtained by *washing the sands of rivers.*

Q. WHERE is GOLD found?

A. This metal is *widely diffused over the surface* of the earth, and there are *few parts* of the world but have yielded it in some proportion.

Q. Mention SOME of the COUNTRIES in which it has been found.

A. It is found in *most parts* of Europe, but only in *very small quantities*, as in the sands of the Danube, the Rhine, the Rhone, the Garonne, the Tagus, &c. The mines of importance are at Kremintz, in Austria, and in the Ural Mountains. Africa furnishes large quantities of gold: it is specially abundant on the coast of Zanguebar, Western Africa, and the Niger. It is also found in Japan and the East India Islands. Large quantities are produced from the alluvial sands of Brazil.

Q. Where of late has it been CHIEFLY FOUND?

A. In *California* and *Australia.*

Q. Where, in CALIFORNIA and AUSTRALIA, has GOLD been found?

A. In California it has been found in the *valleys of the River Sacramento.* In Australia it has been found lying to the eastward of the *Blue Mountains*, in the neighbourhood of *Bathurst;* through the valleys of the *Macquarie River;* and, to the south, in the province of *Victoria.*

CURIOUS FACTS.—The 100,000th part of a grain of gold may be seen by the naked eye; and a cube of gold whose side is but the 100th of an inch has 2,433,000,000 of visible parts. If a silver wire be covered with gold, it may be drawn out into wire of still greater fineness, and still retain this coating of gold; and one grain of gold will in this way coat a surface of wire about two miles and three-quarters in length. The malleability of gold exceeds that of all other metals. Gold leaf can be reduced to the 300,000th of an inch, and gilding to the 10,000,000th. Lace gilding is 1,000,000th of an inch thick, tinfoil 1,000th of an inch, and gold leaf the 200,000th; so that 200 gold leaves are only equal in thickness to one of tin-foil. One grain of gold will cover $7\frac{1}{2}$ inches each way, or 52 square inches; or be 1,500 times thinner than ordinary writing-paper. Its tenacity, however, is greatly inferior to that of other metals. A wire one-thirteenth of an inch thick will not support a greater weight than 150 lbs.; whereas an iron wire of the same diameter will sustain a weight of 560 lbs. It is not an opaque body, like all other metals, for gold leaf transmits a green light, as may be conveniently observed by laying a leaf between two thin plates of colourless glass, and holding it between the eye

and a strong light. It is less fusible than silver, and more so than copper. It is the most perfect conductor of heat—that is to say, if heat be applied to one end of a rod of gold, it will be transmitted from particle to particle, and become sensible at the other extremity of the rod more quickly than through any other substance in nature. Gold may be exposed for ages to air and moisture without undergoing any alteration; and a quantity of it has been kept for thirty weeks in a melted state in a glass-house furnace without the loss of a single grain, and without any change in its nature. But if a small portion of it be intensely heated by electricity, or by the oxy-hydrogen blowpipe, it burns with a greenish blue flame, and is dissipated in the form of a purple powder.

Q. Is not gold ALLOYED BEFORE it is USED for purposes of COINAGE?

A. Yes. Gold is *too soft* for purposes of *ornamentation or coinage without alloy.* The base metal used as an alloy is generally *copper*, though occasionally *silver* and *zinc* are used.

Q. What is PLATINUM?

A. Platinum is a *grayish-white* metal, more *rare*, and on some account more *valuable* even than gold. It occurs chiefly in South America.

Q. When was this metal FIRST INTRODUCED into EUROPE?

A. In the middle of the last century. It derives its name from the American Spaniards, who called it *platina* (*little silver*).

Q. What are the PECULIAR PROPERTIES of PLATINUM?

A. Its *extreme density*, it being the *heaviest* of all known bodies, the impossibility of *melting* it with the strongest furnace heat, and the *resistance* which it offers to the *solvent power of acids.*

Q. Where and in WHAT STATE is SILVER generally discovered?

A. Like gold, silver is a *very widely distributed metal*, and is found more or less in nearly *every part* of the world. Sometimes it is found pure, or native silver; when in combination, it is found with sulphur, as sulphide of silver; with sulphur and lead, as the mineral galena; or, in union with chlorine, as chloride of silver.

Q. What are the CHARACTERISTICS of silver?

A. Pure silver is *harder* than gold, but is still a *soft* metal; when polished it is more brilliant than any other metal; it does not tarnish unless attacked by the vapour of *hydro-sulphate of ammonia* or *hydro-sulphuric acid gas.* Next to gold, it is the most ductile and malleable of all metals.

Silver leaf can be reduced to the 170,000th part of an inch. It can be put into plates of which 110,000 make an inch. It may be drawn out into wire more slender than the finest human hair; and in this way a single grain may be stretched out to 400 feet. Its tenacity is inferior to that of iron, copper, or platinum; its specific gravity is somewhat lighter than lead; it is elastic, and, when hardened by alloy, is highly sonorous.

Q. Which is the MOST USEFUL of all metals?

A. Iron.

Q. Is iron obtained in a PURE STATE?

A. No. This *very important and widely diffused metal* is *scarcely ever obtained in a pure state.*

Q. Where is iron CHIEFLY FOUND?

A. The *ore of iron* is found *abundantly in all countries.* The

principal ores are the *magnetic ore* and *ironstone of mountainous regions*, and the *bag iron* and *iron earth of alluvial districts.*

Iron is said to form two per cent. of the crust of the earth. Great Britain and France contain the most extensive mines in the world. Sweden has large mines of magnetic ore, which produce the best of bar iron. The mines of Denmark are particularly celebrated. At Gellivara, in Swedish Lapland, is a mountain of ore three miles in length. Norway, Russia, Spain, Germany, and Austria have extensive mines. The island of Elba contains one of the most curious known, remarkable for the beautiful play of colours on the ore. In the United States there are numerous and inexhaustible beds of iron ore, particularly along the Alleghany and Appalachian mountains.—*Hughes.*

Q. What are the PRINCIPAL VARIETIES of iron employed in COMMERCE?

A. *Cast iron*, *wrought iron*, and *steel.*

Q. What is STEEL?

A. A *peculiar preparation of iron.* The common plan adopted for converting iron into steel is that called *cementation.* This is done by stratifying bars of wrought iron with charcoal, and exposing them to furnace heat; the union between carbon and iron takes place, and steel is the result.

Q. What METAL ranks NEXT to iron?

A. *Copper.*

Q. Is COPPER as ABUNDANT as iron?

A. Copper, though *less abundant than iron, occurs in many parts of the world.* It is found in pure metallic masses, sometimes of very considerable extent. The copper mines of Cornwall produce more than all the rest in Europe.

Q. What are the other PRINCIPAL COPPER MINES?

A. Considerable copper mines are wrought in the middle and north of Europe, among the Ural Mountains, Russia, and in Siberia. Copper is also furnished from Greenland, Iceland, Tartary, and Japan, Barbary, Southern Africa, and the southern part of South America, the United States, Canada, and Australia.

About half the total amount of copper annually manufactured is produced in South Wales, from the ores brought from various parts of the world, on account of the immense coal-fields of that district. "The practice of Welsh copper smelting," says an eminent writer, "is complex and ingenious; the principle which it involves is, however, simple, and may be rendered intelligible by the general statement, that whilst iron, one of the impurities associated with the greater number of copper ores, has a tendency to unite with oxygen when strongly heated, copper unites, under similar circumstances, with sulphur. This mixed product being heated in contact with siliceous matter, silicate of oxide of iron forms, melts, and rises to the surface, whilst sulphuret of copper, still undecomposed, sinks below. When the iron slag (silicate of oxide of iron) has been removed, the furnace heat is raised sufficiently to effect the decomposition of sulphuret of copper into sulphuric acid, which escapes, and metallic copper, slightly contaminated with oxide of copper, remains. The metal holding this small portion of oxide is deficient in malleability; hence, the oxygen of the oxide must be removed. This is accomplished by the process of copper-refining, as it is termed. The rough material being liquefied by fusion, powdered charcoal is added, and the whole stirred by a green wooden pole. It is almost unnecessary to remark that the pole, thus circumstanced, burns, evolving oxygen, the removal of which is consequently effected."

Q. What are the CHARACTERISTICS of copper?

A. It is *reddish* in colour, *soft*, *malleable*, *fusible at a strong red heat.* It is tarnished by moist air, resulting in oxide of copper or verdigris.

Q. Is ZINC WIDELY DIFFUSED over the earth?

A. Not to so *great an extent* as iron or copper; but in those places where it exists it is found in abundance.

Q. What are the CHARACTERISTIC PROPERTIES of zinc?

A. The properties of zinc *materially alter* in proportion to the degree of heat to which it is raised. After being cast, if permitted to cool down to the temperature of the common atmosphere, zinc is brittle, and is comparatively easily broken. This brittleness may be greatly increased by raising the temperature. At four hundred degrees F., zinc is so brittle as to be easily powdered.

Q. Where are the PRINCIPAL TIN MINES of Europe?

A. In *Cornwall.* These are of very ancient date, and are also very extensive. They are said to have been worked by the Phœnicians.

Q. In what OTHER COUNTRIES besides England are tin mines found?

A. The mountains of *Germany*, and *Gallicia*, in Spain, produce tin; it exists in Mexico, Chili, the United States, the East Indies. The purest is obtained from Malacca.

Q. Is LEAD WIDELY DIFFUSED?

A. Yes. It is found more or less *in all countries;* in the Ural Mountains and in Peru, it is, however, extremely rare. This very abundant and useful metal is rarely found pure. The presence of particles of silver and other matter deteriorates its value for many important purposes where pure lead is absolutely necessary.

Q. In WHAT ROCKS are the PRECIOUS STONES most abundant?

A. Most of the precious stones occur in the *igneous rocks*, especially in *granite*, or in the *sand* and *gravel* formed by the destruction of these rocks.

MINES.

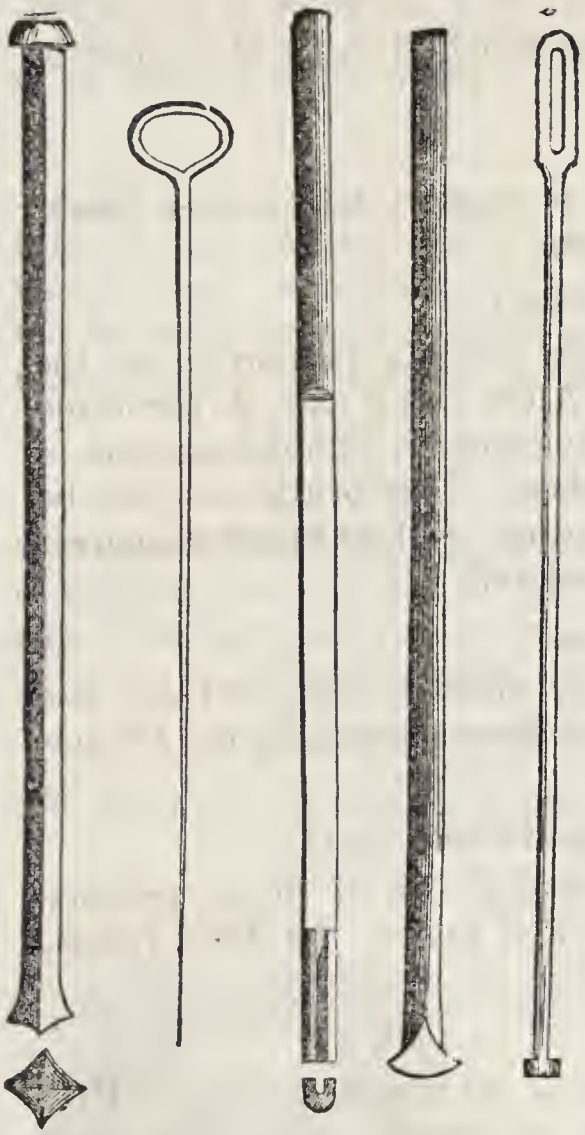
Q. For WHAT PURPOSES are MINES EXCAVATED?

A. 1. For the *working of veins containing the ores of metals;* and 2. For the working of such minerals as generally *lie in beds*, such as *coal mines*, *ironstone mines*, or *limestone mines.*

Q. How is the operation of mining, in a COAL MINE, for instance, COMMENCED?

A. This is done by *boring the earth*, in order to ascertain the exact *position* of the strata or beds of coal before any great operation is undertaken.

Fig. 237.



TOOLS EMPLOYED IN MINING OPERATIONS.

Q. Describe the SORT of INSTRUMENTS used in BORING?

A. The rods commonly used are made of the best Swedish iron, about an inch and a quarter square. Each rod is three feet in length, having screws at either end. The chisels for boring are eighteen inches in length, and about three inches in breadth. There are besides a number of other instruments, called wimbles, sludgers, rounders, &c.

When bores are but a few fathoms in depth, the whole operation is performed by manual strength; but when a very deep bore is to be made, a set of wooden triangles, with a pulley, crane, or windlass, is used. There are professional bore masters in the coal districts, who undertake to put down bores for coal, and to register the strata passed through, at the rate, when no uncommon difficulties occur, of six shillings a fathom for the first five fathoms, and an increase of six shillings a fathom for every additional five fathoms.

Q. Does the work of the miner simply consist in EXCAVATING the ROCK?

A. No; the work of the miner is of two sorts—excavating the ground when soft, blasting it when hard. Tools called the *borer*, or jumper, and hammer, are used for this latter process.

Q. What SORT of tool is the BORER, or JUMPER?

A. It is an *iron rod* or *circular bar* about *two feet in length*, and formed into a flat, sharp edge at the end, which is driven into the rock and made to revolve in the process so as to expose the cutting edge to different surfaces of the rock. The matter thus pulverised is drawn out from time to time; and when the hole is of a sufficient depth, it is charged with powder. A piece of copper wire having a loop at the end, is then introduced—the charge is then rammed down—the wire withdrawn—and a train of powder inserted in its place. The train is then fired by a slow match, and the explosion takes place; the rock is blasted, and the miners' work greatly facilitated.

Q. In the EXCAVATION of a MINE, what IMPORTANT CONTINGENCIES have to be taken into consideration?

A. One of the first, and, at the same time, one of the most important, is that of *drainage:* water rapidly filters in, and must be worked out.

Q. What means are USUALLY EMPLOYED to answer this purpose?

A. In the first place, this may be done by what is called a *horse "whim"* or a *"gin;"* but this is only serviceable when the mine is not very deep, and when the quantity of water to be drained off is but trifling.

Q. What is a "WHIMSEY," or "GIN?"

A. An application of machinery by which *iron baskets are kept continually ascending and descending the shaft*, one basket being emptied at the mouth while the other is filling at the bottom of the pit. It is worked by horses, and its application on a large scale is enormously expensive.

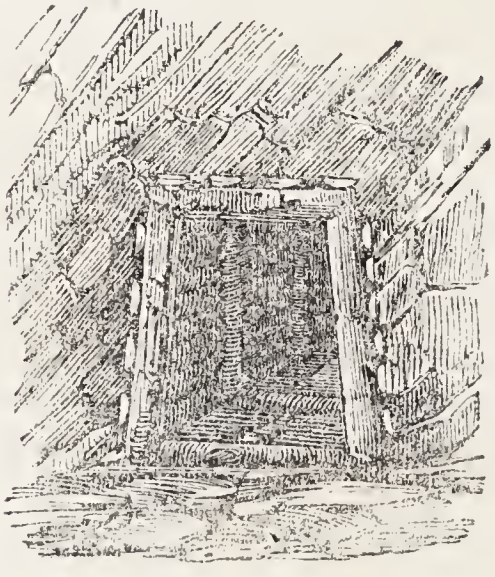
Q. What OTHER MEANS are adopted for the drainage of mines?

A. The *best* and *cheapest* in the mining districts of England is that of the *steam-engine.* In our coal mines the steam-engine is the only power employed for drainage, and in deep and extensive works the motive power is employed for extraction also.

Q. What is the NEXT POINT to be considered in the working of a mine?

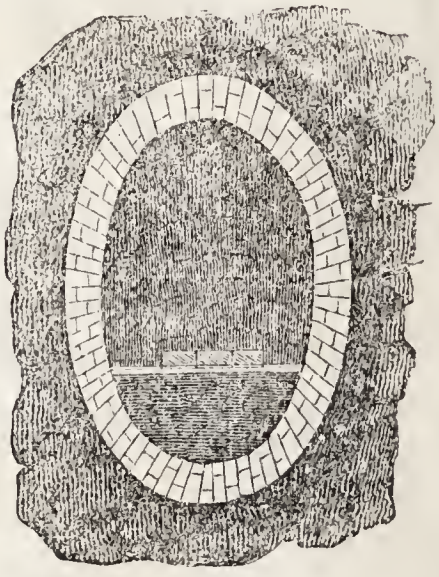
A. The *support* to secure the excavations, which will depend very much on the nature of the soil.

Fig. 238



LEVEL.

Fig. 239.



CIRCULAR GALLERY.

Q. What mode of SUPPORT is generally employed?

A. There are *three kinds* of supports used in the excavation of mines: 1, by leaving pillars of the original rock; 2, by walling with brick or stone; 3, by timbering.

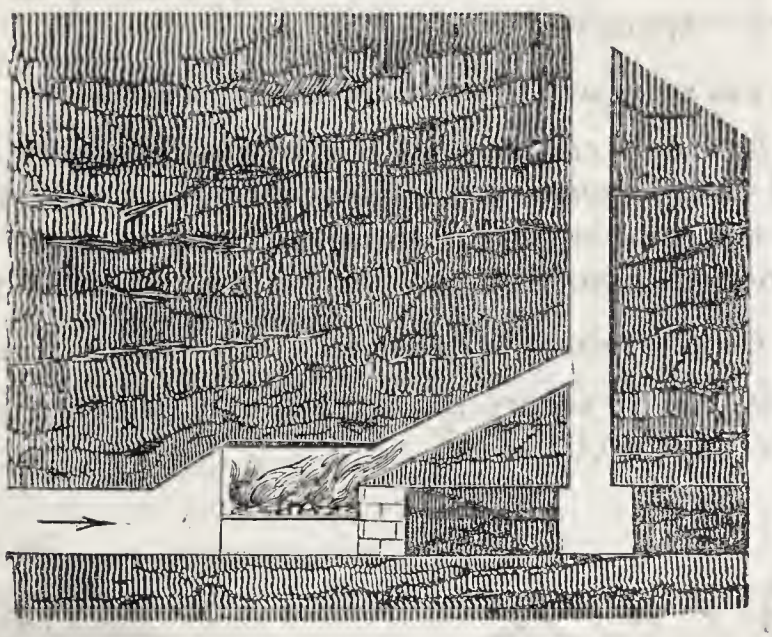
In fig. 238 is shown what is termed a *level*, and which consists of three pieces of timber, arranged something like a doorway, narrower at the top than at the bottom. Levels and shafts are also, in some cases, supported by walling of brick or stone work, as indicated in fig. 239.

Q. What means of VENTILATION are adopted in mining operations?

A. The ordinary arrangements of the works and the communications continually kept up with the surface, in most cases, furnish sufficient air without adopting any mechanical means of supplying it. An apparatus, known as the *cylindrical exhauster*, was invented some years ago, which, being placed at the mouth of a shaft, drew up the foul air, and consequently the pure air rushed in to supply its place, but such applications are not generally necessary.

In coal mines the ventilation is much more difficult than in ordinary mines. It is effected by two shafts, called the *down-cast* and *up-cast*. The up-cast shaft has a large

Fig. 240.

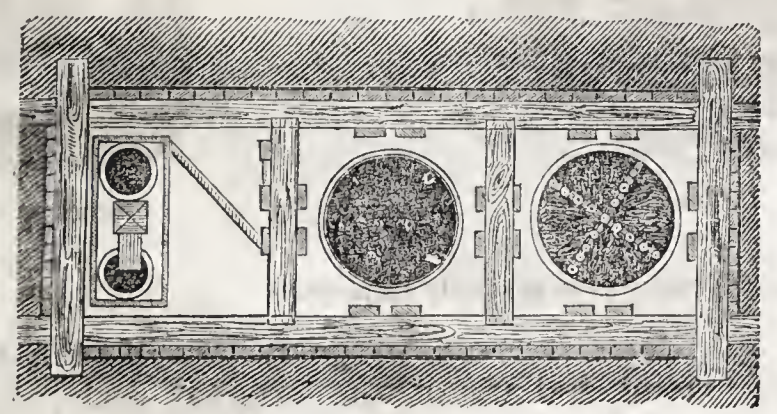


VENTILATING APPARATUS.

furnace continually burning near the bottom of it (see fig. 240), and the air being considerably rarefied at this point, an ascending current is formed, which passes upward with great velocity, and causes a descending current to pass through the down-cast shaft, to supply its place.

MINE SHAFTS.—Shafts of extensive dimensions are usually divided into several compartments, which are devoted to different purposes. Thus fig. 241 represents the plan of a

Fig. 241.



shaft divided into three compartments, of which two are devoted to the purposes of extraction, while the third serves as a passage for drainage and as an entrance for the workmen.

Q. How is the PRODUCE of a MINE brought up to the SURFACE of the ground?

A. This is very simply effected by adapting an efficient motive power to a convenient form of winding apparatus.

Q. What MOTIVE POWER is commonly employed?

A. Steam.

Fig. 242.

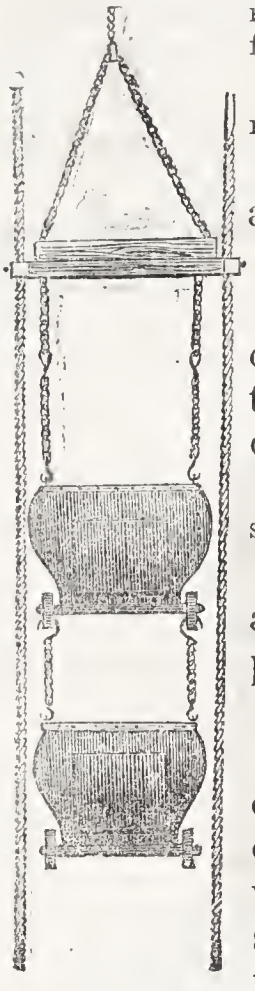


Fig. 242 represents two mining baskets, one above the other, connected by strong chains, and supported by cables, which carry them from the bottom to the mouth of the shaft.

Q. Is similar apparatus employed in the ASCENT and DESCENT of miners to and from the pit?

A. Yes; they are lowered by a motive power from above.

Q. Is there not considerable DANGER attending such transit?

A. Mining operations are altogether of a very perilous character, but much has been done by scientific investigation and mechanical contrivance to lessen these dangers.

Q. Has any SAFETY APPARATUS been invented for ascending and descending mines?

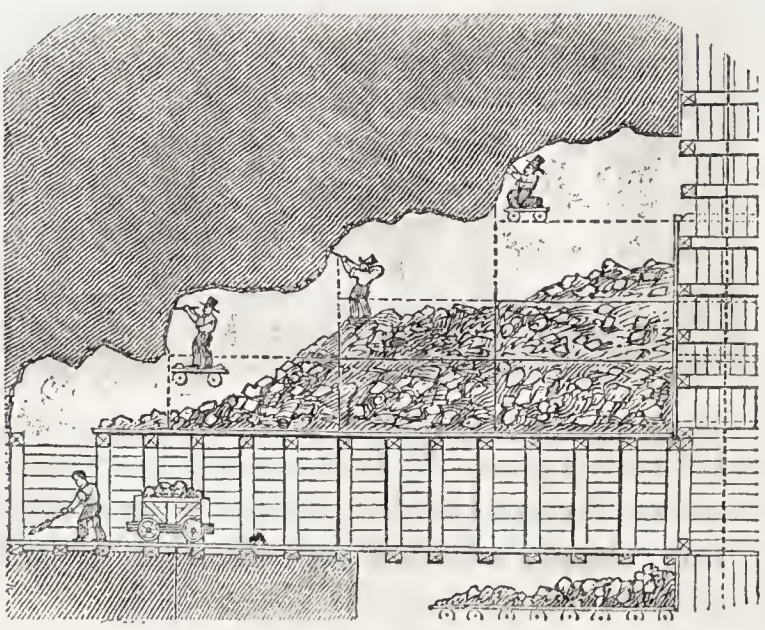
A. Fourdrinier's invention has this object in view, and has been severely tested in several mines, and proved to afford a great amount of safety to the miner.

Q. What is the character of this invention?

A. It consists of a cage or basket, which carries tubs of coal attached to guide rods or chains from the side of the shaft. Supposing that the cable or chain by which the whole is supported snaps, the self-acting springs or arms forming levers, attached to the top of the cage, are freed, and these wedging themselves securely against the guide-rods, its descent is immediately averted.

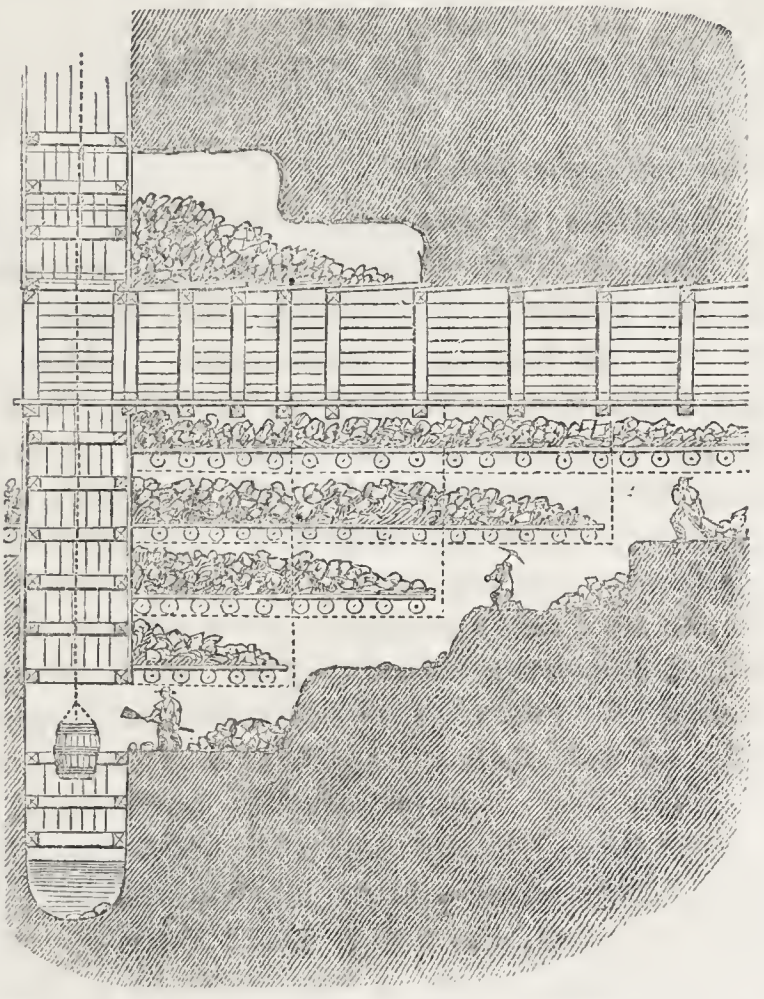
In an experiment made at Usworth colliery, Durham, the cage containing two tubs loaded with coal, the whole weight of the cage, tubs, and coal being forty-eight hundred-weight, when the rope was disengaged the apparatus instantaneously took effect, and the whole mass was firmly fixed to the guides. On another occasion, at the same colliery, the cage, with a total weight of fifty hundred-weight, was safely arrested in its descent, which but for the safety apparatus must have been precipitated to the bottom of the

Fig. 243



shaft, a thousand feet below. But this was not all. Two of the workmen then placed themselves in the cage, and by a touch of their hands stopped this weight of fifty hundredweight, and themselves in addition.

Fig. 244.

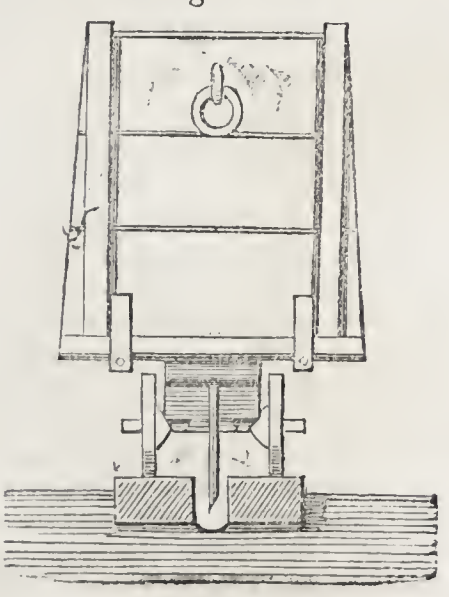


The preceding diagrams (figs. 243, 244) represent two of the methods adopted in working a mine—the first from below, the second from above.

Q. Does the ore of a mine undergo any MECHANICAL PREPARATION from the hands of the miner?

A. It does; and such mechanical preparation is technically known as *dressing*.

Fig. 245.



Q. What is the PURPOSE of this preparation?

A. The operation termed *dressing* is, in fact, separating as far as possible the *earthy matter* from the metallic ores.

Q. Upon what PRINCIPLE is the operation conducted?

A. The operation is conducted on the principle of the difference of specific gravity between earthy and metallic matter.

Q. Describe the ORDINARY PROCESS.

A. The dressing-floors of a mine are always placed near the principal shaft, and are always provided with a channel of water. The floor is paved, and there are side ranges of sheds for the labourers to work in. The ore is conveyed to them by a small railway, in an apparatus similar to that which is seen in fig. 245.

Q. What is the FIRST OPERATION which the ore undergoes?

A. The first operation is that which is technically described as *picking*. The ore, brought from the mine in rough, irregular masses, is broken into smaller pieces. When the sparry matter is picked out and rejected, the remaining portion of the ore is comparatively pure.

Q. Describe the SUCCEEDING PROCESSES.

A. These processes consist of "crushing," "jigging," and "stamping." The first of these operations is performed by a machine called the grinder or crushing mill, which consists of iron rollers moved by mechanical contrivance. Above them is a "hopper," into which the ore is thrown, through which it passes, and is crushed by the iron rollers. The pure and impure matter, the metallic and the earthy particles, are still as much mixed as ever, and another process is rendered necessary. It is therefore transferred to the brake sieve, or jigging machine, which consists of a wooden frame, open at the top, and provided with a sieve at the bottom. By a peculiar motion, this sieve containing the ore is plunged again and again into a cistern of water; a movement which causes the heavy metallic particles to settle at the bottom, and throws the lighter or earthy matter to the top. The separation, however, is not complete. The earthy matter thrown to the top still contains metallic ore, and to extract this from the refuse matter, several processes are employed, such as grinding, washing, stamping, &c. Thus, by repeated washing and grinding, the metallic ore is separated to a great extent from earthy matter; but it still contains many impurities, for, when afterwards placed in the furnace, these impurities become fused, and are known as slag.

Q. Were mining operations conducted at an EARLY PERIOD of the world's history?

A. They were, according both to sacred and profane histories. Thus Moses ascribes the first use and manufacture of metals to Tubal Cain; and metallurgy was known both to the Egyptians and Greeks—such as gold, silver, copper, tin, and iron.

Such facts as these, however, do not, it has been very justly observed, "imply any great knowledge of mining, properly so called; as it is well known that metalliferous deposits are often found near the surface, frequently in a state of extreme purity, as gold and silver, for example; and in early ages, when they had been so much less ransacked by the miner, these superficial deposits must have been much more abundant than at present, and probably formed a large proportion of the metallic products of those times."

Most of the mines of antiquity were probably of a similar nature to the stream works of Cornwall; and it appears from Strabo that the Phœnicians at that early time used to trade to Cornwall for tin and lead. In early times the demands for the metals could not have been very great; their use was then either as instruments of luxury or war, and thus confined to a limited class; so that the quantity found near the surface was, in all probability, fully adequate, leaving but little inducement for deeper and more laborious research. There is, however, evidence enough to show that operations similar to those in modern mining were carried on by the nations of antiquity. Herodotus observes that mountain in the island of Thrasos was completely burrowed by the Phœnicians, in their search for the precious metals; and the curious fragment of Agatharchides, preserved in Diodorus, shows that the art of forming shafts and passages for exploring mines and pro-

curing the metals was well known in Egypt. The silver mines of Laurium, in Attica, were worked by the Athenians, to some extent at least, as early as the beginning of the fourth century B.C. Under the Romans, the quicksilver mines of Almaden, in Spain, were extensively worked.

Q. Was not the art of mining in England NEGLECTED for a long time?

A. Yes; during what is called the *Saxon period* the mines were much neglected. Before and during the Roman conquest they were a source of *considerable wealth* to the country; but after the establishment of the Saxons in England the troublous state of the land drew away attention from them, and up to the time of the Norman invasion they were suffered to continue in neglect.

Q. What occurred with respect to British mines SUBSEQUENTLY to this date?

A. After that period the mines were, for a considerable time, *worked by the Jews;* but the subject was, to a great extent, still suffered to remain in neglect; and in the reign of Queen Elizabeth a number of *German miners* received every encouragement to settle in England, in order that this most important commercial undertaking might be revived.

It was by the wealth of the lead mines of Cardiganshire that Sir Hugh Middleton derived much of his large fortune; a fortune which was so nobly spent in the formation of the New River.

Q. When was the process of BLASTING WITH GUNPOWDER in mining operations FIRST INTRODUCED?

A. It is probable that gunpowder was *first employed* in England for the purpose of *blasting mines* in the reign of James I.

"The application of gunpowder to the purposes of mining first took place in Hungary, or Germany, about the year 1620; and it was first introduced into England at Ecton, in Staffordshire, about the year 1620, by some German miners, brought over by Prince Rupert. It was in use in Somersetshire about 1684; and it was not till after this period probably that the Cornish miners became acquainted with this powerful assistant in their operations. Its importance may be judged by the amount of the present consumption in the mines of Cornwall alone, which has been calculated at an annual value of about forty thousand pounds sterling."—*Taylor.*

Q. Had the invention of the STEAM-ENGINE any CONSIDERABLE INFLUENCE on the progress of mining?

A. It had, as the *introduction of Savery's engine* into our mining districts completely *altered the principles* of this important art, and very considerably extended its utility. It was *first applied* to the *drainage of mines.*

Q. Who was the FIRST IMPROVER of Savery's engine?

A. Thomas Newcomen, of Dartmouth, in Devonshire, who, having had occasion to witness experiments made with *Savery's steam-engine* in the tin mines of Cornwall, and to observe the danger and difficulties attending its application to the purposes of drainage, was led to the invention of the *atmospheric steam-engine.*

Q. When were the GREATEST IMPROVEMENTS introduced?

A. The greatest improvements in the *application* of steam power to the art of mining were attributable to the *discoveries of Watt.* Besides many other advantages, they were far more *economical* than those of former time.

Q. What are the MOST RECENT IMPROVEMENTS which have been introduced into the art of mining?

A. They have been chiefly directed to the *safety of the miners*, or to the *mechanical treatment* of the *ores*.

STONE.

Q. In selecting a stone for ARCHITECTURAL purposes, how may we be able to form an opinion respecting its DURABILITY and PERMANENCE?

A. By visiting the locality from whence it was obtained, we may judge from the *surfaces* which have been *long exposed to the weather* if the rock is liable to *yield to atmospheric influences*, and the conditions under which it does so.

"For example, if the rock be a granite, and it be very uneven and rough, it may be inferred that it is not very durable; that the feldspar, which forms one of its component parts, is more readily decomposed by the action of moisture and frost than the quartz, which is another ingredient; and therefore that it is very unsuitable for building purposes. Moreover, if it possesses an iron-brown or rusty appearance, it may be set down as highly perishable, owing to the attraction which this metal has for oxygen, causing the rock to increase in bulk, and so disintegrate."

Q. Why are the SANDSTONES, termed FREE stones, ILL ADAPTED for the external portions of exposed buildings?

A. Because they *readily absorb moisture;* and in countries where frosts occur, the *freezing* of the water in the wet surface continually *peels off* the external portions, and thus, in time, all ornamental work upon the stone will be defaced or destroyed.

Q. Why do some species of rock become HARDER when taken from the quarry and exposed to the atmosphere?

A. This quality, in some species of stone, arises from the fact that the *water* contained in it, when forming part of the natural rock, *evaporates*, and the stone, becoming *dryer*, becomes *harder*.

Q. Why do some stones, although hard when first quarried, become FRIABLE, and fall to pieces, when exposed to the atmosphere?

A. Because they contain *clay* or *alumina* in such a state as to *readily absorb moisture* from the atmosphere; and through the agency of the moisture the particles *lose their cohesion* and fall apart.

SPRINGS.

Q. What is the ORIGIN of springs?

A. The *water* falling upon the earth *sinks downwards* through the sand and porous materials, until an impervious *bed of clay* or *rock* is reached. Here the *water accumulates*, and finally *bursts out* at some point where the impervious bed or strata comes to the surface in consequence of a valley or excavation.

Q. Why does not the water OOZE OUT everywhere along the LINE of JUNCTION of the two formations—the gravel and the rock or clay—so as to form one CONTINUOUS LAND soak, instead of a few springs only, and these far distant from one another?

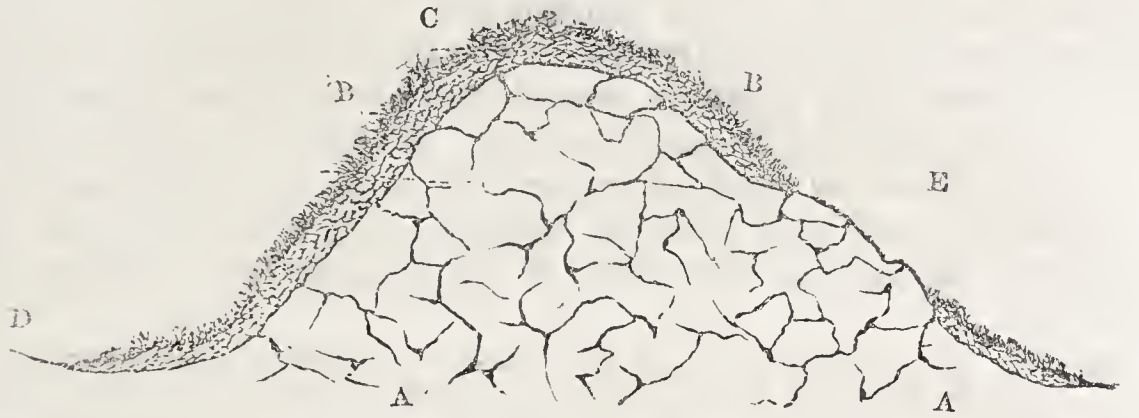
A. For *two reasons:* first, on account of *rents and fissures* in the strata, which act as natural drains; secondly, the existence of

inequalities in the upper surface of the impermeable stratum, which lead the water, as valleys do on the external surface of a country, into certain low levels and channels.

The water-tight rocks of the earth are of four different kinds, each kind giving rise to a different form of spring. They are :—

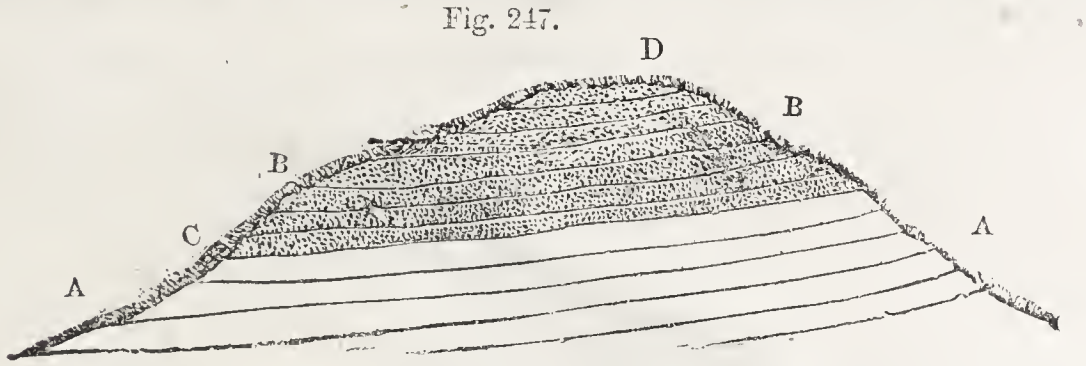
1. Where the underlying water-tight rock is a ridge that bends down on each side.
2. Where the rock is an inclined plane in one direction.
3. Where the sides of the rock curve up on both sides, like the inside of a basin.
4. Where rocks have been dislocated by what is called a fault.

Fig. 246.



The above diagram represents the first instance of these varieties, and shows the concave curve of a water-tight rock. A represents the mountain mass of a water-tight rock. B a gravelly bed, formed from the rock A, and resting on it. C the vegetable mould, which covers A and B. From D to E is a well, formed at the bottom of the mountain; and E is another spring, bubbling at a high elevation, on one of its sides.

Fig. 247.



In this diagram is shown a series of inclined beds—the second instance indicated of water-tight rocks—and forms the base of a hill. A is the series of inclined beds ; B the strata of gravel, or sand, resting on the inclined beds ; C the point of junction of the porous bed of sand, or gravel, with the water-tight strata, in which the permeating water will appear as a spring at a high elevation on the side of the hill. No spring of water can, under the circumstances, appear at D. The copious and continual flow of such a spring must depend on the depth and extent of the beds B B.

Q. Why does the water COLLECT in an ordinary WELL ?

A. An ordinary well consists of an *excavation* continued until a *stratum is reached* that is permanently saturated with water. These wells are not commonly supplied with springs, but merely by the draining of the water, which exists within the circuit of a few yards, into a cavity.

Q. Why do WELLS and springs FAIL oftentimes in DRY WEATHER ?

A. Because they are supplied by the *water falling as rain*, which percolates from the surface of the earth.

Q. What is an ARTESIAN well?

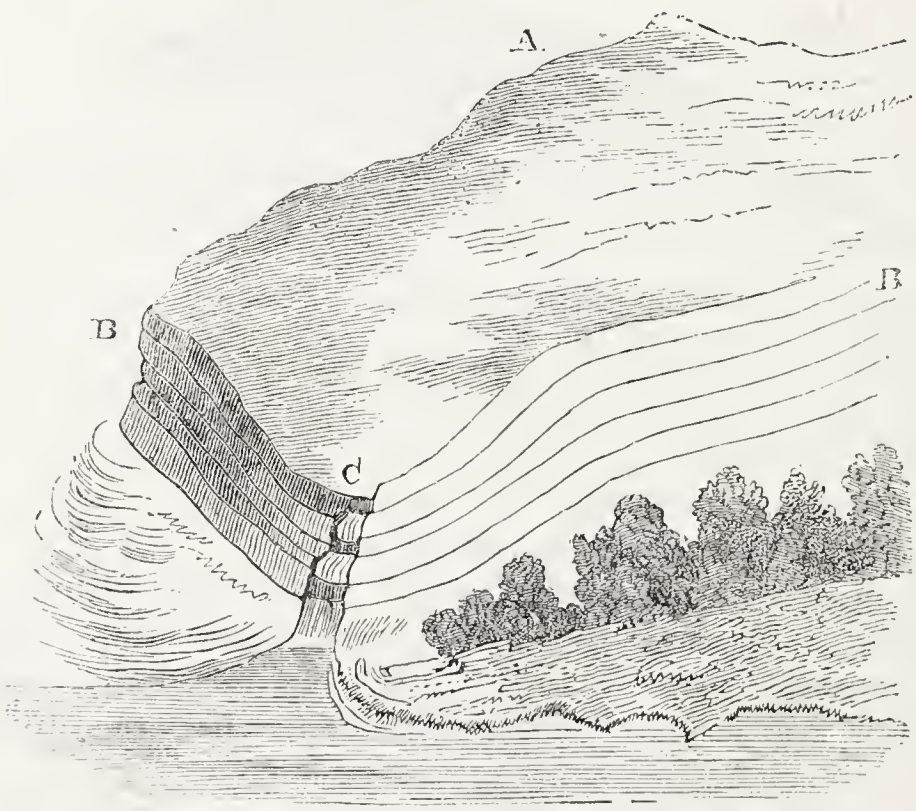
A. Water is sometimes obtained by *boring into the earth* with a species of auger, until a vein or sheet of water is found, which rises to the surface through the cylindrical excavation. Such excavations are called Artesian wells.

Q. How do you ACCOUNT for the water RISING to the surface in the Artesian well?

A. Strata which are *pervious* frequently alternate with others which are *not* so; or may form a *basin*, the area of which is partially filled with *clay*, through which water cannot pass; in such a case it is obvious that the bed of sand beneath the clay, fed by the rain which descends on the uncovered margin of the basin, must form a reservoir where the water will gradually accumulate beneath the central layer of clay, through which it cannot escape. If the bed of clay be penetrated by natural or artificial means, the water must necessarily rise to the surface, and may even be thrown up in a jet to an altitude which will depend on the level of the fluid in the subterranean reservoir.

Thus, if a sandy stratum, acting as a filter, occupies an inclined position between the two other strata impervious to water, such as clay, the water being absorbed by the superficial parts of the strata (which may be of very great extent) will penetrate through its whole depth, and, finding no egress below, on account of the basin-like form of the stratum, or from its resting at the lower termination upon a compact rock, will accumulate. The porous strata, therefore, becomes a reservoir to a greater or less extent; and if, by boring through the superincumbent mass, we form an opening into the stratum, the water will rise in it, and flow over in a jet proportional to the height of the water accumulated in the stratum from whence it flows.

Fig. 248.



The above engraving represents a spring in a mountain side in Switzerland. The upper part of the hill A is formed of a large, deep mass of gravelly soil. Through this mass rain-water and melted snow penetrates, till it reaches the impervious stratum, B B.

A kind of trough is formed (C) by the carrying upward of these beds, when the waters gush out into a powerful spring.

Q. Are the ARTESIAN WELLS of MODERN INVENTION ?

A. Such wells were *known in China* from a very *remote period*.

Q. WHY are they called ARTESIAN ?

A. From the French province called *Artois;* or, anciently, *Artesium;* it being in this district that wells of this description were *first formed* in Europe.

Q. Describe the meaning of the terms ARENACEOUS and ARGILLACEOUS.

A. The term arenaceous, or sandy, is given to such soils and rocks as easily absorb or drink in the water that falls upon them. Argillaceous, or clayey, denotes such soils and rocks as retain the water, or through which water penetrates with great difficulty

Q. How does the water PASS THROUGH these porous beds ?

A. It descends by its own gravity lower and lower, until it finds a stratum of clay, or rock, which is impervious—that is to say, through which it cannot pass.

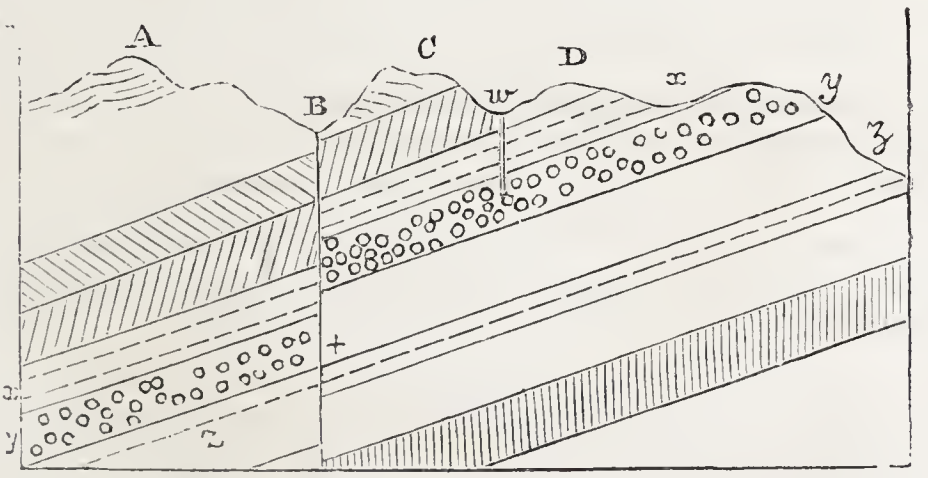
The principle here involved has been already explained. When the impervious rock curves upward, the water produces wells on each side of the hill ; when the surface is an inclined plane, the water flows along the slope in one direction, and appears as a well on one side only of the mountain. It is, therefore, evident that when water reaches an impervious stratum it must accumulate as a reservoir, and will then ooze out by any outlet which it can effect.

Q. How is it that the water does not ooze out along the WHOLE LINE of JUNCTION between the porous stratum and the impervious rock ?

A. 1. Because, in loose, gravelly beds, there are always to be found fissures which act as drains to the water.

2. Because the dents and curves in the hard rock cause the water to accumulate more in one part than another, and so overflow.

Fig. 249.



In fig. 249, let A, B, C, D, *x*, *y*, *z*, represent the section of several miles of country, with three different rocks resting on each other, *x*, *y*, *z*. The rocks *x* and *z* are impervious to water ; the rock *y* is porous ; therefore the rain enters between the rocks *x* and *z*. It will be noticed that the beds are shown as fractured by some dislocation from beneath. This is called by geologists a fault. It has produced a fissure, or crack, with an outlet at B. Now, the water which has entered the bed *y* is stopped by this fissure, which has broken the continuance of the bed, and the water is met by an impervious rock.

Then let the rock *y* be tapped by the Artesian process, and the water immediately rises at *w*. What is thus accomplished by artificial means at *w*, is effected by the natural fissure at B. There the water rises as a permanent spring. The difference between the two is this: the artificial boring is a mere puncture, as to extent; but the effects of the "fault" are felt for miles downwards. On this account, springs produced by faults are more permanent than others.

SOIL.

Q. What is a NATURAL SOIL?

A. Natural soils are *merely decomposed parts of the subjacent rocks*, mixed with the decomposed portion of vegetable substances which have grown or fallen upon it, with some animal substances.

"Wherever the surface of the earth is not covered with water, or is not naked rock, there is a layer of earth more or less mixed with the remains of animal and vegetable substances in a state of decomposition, which is commonly called the soil. The nature and composition of the soil, and consequently its greater or less aptitude to the growth and maturity of vegetable productions, depend chiefly on the proportion and mechanical structure of the various substances of which it consists. When the soil is favourable to the chemical action by which the elements are combined to form vegetable substances, and admitting the quantity of air and moisture, without which this chemical action cannot take place in any given climate or temperature, vegetation goes on rapidly, and all the plants which are suited to the climate grow in the greatest perfection, and bear abundant fruit."

Q. What is the NAME given to the vegetable and animal products mixed with the mineral ingredients of a soil?

A. *Humus.*

"Organic matter is, no doubt, essential to great fertility in a soil; but some soils require more of it than others. *Humus*, which is the form which organic matter naturally comes to by slow decomposition in the earth, gives out certain elements which the roots can take up in their nascent state, and from which they obtain the carbon which is so abundant in all vegetable productions. But organic matter, in every stage of its spontaneous decomposition, keeps the pores of the soil open, and admits, if it does not even attract, air and moisture to the fibres of the roots. In all rich soils, which have been long cultivated, especially in gardens, there are particles, of a dark colour and fibrous texture, which in the microscope appear like minute logs of charred wood. These keep the soil open, and supply carbonic acid, when the air reaches them, or they are slowly transformed into humus, which remains inert as long as it cannot imbibe oxygen and form carbonic acid by a species of slow combustion. *Humus* is undoubtedly one of the chief causes of fertility."

Q. How are soils DISTINGUISHED ONE FROM ANOTHER?

A. By a comparison of their texture as to the size and character of the particles, and tracing their original formation.

Q. How can you ASCERTAIN the SIZE and CHARACTER of the PARTICLES of soil?

A. By drying it thoroughly, and then slightly bruising it with a wooden pestle in a mortar.

Q. What BENEFICIAL EFFECT do loose stones and rocks have upon dry, porous soils?

A. They *retain moisture* in the soil by preventing the evaporation which would otherwise take place. In high lands they serve to condense fogs and low clouds, and thus add to the moisture of the subjacent soil.

Q. What is MARL?

A. Any *rock* which contains a considerable *portion of carbonate of lime*, and which rapidly *disintegrates* on exposure to the atmosphere, is called *marl*.

MINERALOGY.

CHAPTER LXX.

CHARACTERISTICS AND CLASSIFICATION OF MINERALS.

Q. What is MINERALOGY?

A. Mineralogy is that branch of natural history in which *mineral substances* are *classified* and *distinguished*, their uses made known, and their modes of occurrence in the earth pointed out.

Q. What CONSTITUTES a mineral species?

A. A mineral species is a *natural inorganic body*, with a definite chemical composition, and a regular determinate form or series of forms.

Q. Into what FOUR CLASSES may mineral substances be divided?

A. Into the *silicious* and earthy minerals, the *saline* or salts, the *inflammable*, and the *metals*.

Q. What are the SILICIOUS and EARTHY minerals?

A. The silicious and earthy minerals comprise all those species which derive their principal characteristics from *silica* and the *earths*. In this class would be included most of the *common stones*, and the constituents of all *ordinary rocks*.

Q. Will you give some EXAMPLES of the silicious and earthy minerals?

A. Those in which *silica predominates*, as the *flints*, *quartz;* those in which alumina, lime, and magnesia form essential constituents, as common clay, slates, soapstone, mica, marble, limestone, spar, &c.

Q. What SUBSTANCES would be included in the SALINE class?

A. Most of the *combinations of the acids and chlorine* with the *alkalies* which exist in the mineral kingdom; as saltpetre or nitrate of potash, common salt or chloride of sodium, and sal ammoniac or chloride of ammonium.

Q. What MINERAL SUBSTANCES would be included within the class of INFLAMMABLES or COMBUSTIBLES?

A. *All* the mineral combustible bodies, except the metals; such as sulphur, coal, amber, bitumen, &c.

Q. What MINERALS are included in the class of metals?

A. All those mineral substances which are composed either *entirely of metals*, or of which metals constitute the *most considerable part*.

Q. How MANY mineral species are known?

A. About *four hundred* mineral species are known; the varieties of these species are almost infinite. Thus carbonate of lime, a mineral species, occurs as marble, as chalk, as Iceland spar, as dog-tooth spar, and in many other forms, more or less common.

Q. What TWO mineral species occur in the GREATEST ABUNDANCE upon the surface of the earth?

A. *Quartz* and *carbonate of lime.*

Q. What is QUARTZ?

A. Quartz is nearly *pure silex*, or *oxide of silicum.* When pure, it is transparent or translucent, and has a vitreous or glassy appearance. It then receives the name of rock-crystal.

Q. What is AMETHYST?

A. When the *rock-crystal* is of a rich purple colour, it is called amethyst; when the colour is faint red or pink, it is called *rose* quartz.

Q. What OTHER precious stones are included under the varieties of QUARTZ?

A. The *jasper*, the *carnelians*, the *opal*, the *agate*, and the like.

Q. What is the COMPOSITION of the RUBY and the SAPPHIRE?

A. The ruby and the sapphire consist *principally of aluminous earth*, with a little *silex* and *oxide of iron.*

Q. How do these gems appear to have been FORMED?

A. They appear to have been *crystallised through the action of heat* in the rocks in which they are found. This supposition is rendered almost certain by the experiments of French chemists, who have succeeded by a similar method in producing artificial rubies, in every respect resembling the natural gems.

Q. What is FELDSPAR?

A. Feldspar, a constituent of all granite rocks, is composed of *silex*, *alumina*, and *potassa.* It is by the decomposition of this mineral that much of the potash existing in the soil, and absorbed by plants and trees, is furnished.

Q. How is the POTASH extracted from the feldspar, and made accessible to the roots of plants and trees?

A. When the feldspar decomposes, the potash, being soluble, is *washed out*, acted upon by the atmosphere, and imbibing carbonic acid, always present in the air, becomes converted into carbonate of potash. The carbonate thus formed is *disseminated throughout the soil*, and is then taken up by the roots of plants.

Q. What is MICA?

A. Mica is composed of nearly the *same ingredients as feldspar*, together with oxide of iron. It is often colourless, but frequently green, black, or smoky. It is well known from its capability of division into exceeding thin, transparent, elastic plates. From its ability to resist the action of heat, it is much used for the doors of stoves and furnaces.

Q. What is SOAPSTONE?

A. A compound of *magnesia* and *silica.* It is generally of a light-gray colour, earthy texture, and unctuous to the touch.

Q. What is SERPENTINE?

A. Serpentine has much the *same constitution as soapstone.* It is

generally of a *greenish colour*, variegated with spots of green of different shades. With a mixture of carbonate of lime, it forms the *verd-antique marble*.

Q. When feldspar decomposes, and its potash is washed out, what NAME is given to the compound formed by the two remaining constituents?

A. Porcelain clay.

Q. In what MANNER are minerals, and particularly metallic ores, DISTRIBUTED in the earth?

A. In *layers or masses;* in *lodes* or *large veins* running parallel with, or traversing, the general course of the stratification of the rock; in nests or pockets; in nodules, which are concretions or accumulations of minerals of small extent; and in small veins, which are either branches of heavy veins, or an expansion of a large vein, ramifying the rock in all directions.

Q. How are minerals DISTINGUISHED from each other, and classified?

A. By their *characteristic differences;* these are principally—1, their form; 2, their physical; and, 3, their chemical properties.

Q. What is that DEPARTMENT of mineralogy CALLED which treats of the FORM of minerals?

A. Crystallography.

Q. What do we UNDERSTAND by the PHYSICAL CHARACTER of a mineral?

A. Its *cohesion*, *specific gravity*, *colour*, and its *relation to light*, *electricity*, and *magnetism*.

Q. Are there any LIQUID or FLUID minerals?

A. One or *two species* of minerals, as *native mercury*, *naphtha*, &c., are liquid.

Q. What is the CLEAVAGE of a mineral?

A. When its particles are arranged in such a manner that they exhibit *less cohesive power* in one *direction* than in another, it is said to possess cleavage, in the same manner as wood is more easily cleavable in the direction of its fibre than across the grain. All minerals possessed of a crystalline structure are cleavable. Some, however, exhibit this property more strikingly than others; thus, mica is cleavable into the thinnest laminæ or plates.

Q. Does the FRACTURE, or manner in which a mineral breaks, serve, in a measure, to DISTINGUISH it?

A. It *does*. It may be even or uneven, or conchoidal; as, for example, in the case of flint. It may be splintery or earthy, as in the case of chalk.

Q. Does the HARDNESS of a mineral serve to CHARACTERISE it?

A. In the description of a mineral particular attention is always paid to its *hardness*. Many minerals are sufficiently hard to resist the best files, while others are so soft as to admit of being scratched by the finger-nails. Of two minerals, that, of course, is the hardest which will scratch the other without being itself scratched.

Q. What is the SCALE of HARDNESS?

A. A scale of hardness has been constructed, consisting of ten well-known minerals, so arranged that each one will *scratch* that which *precedes* it, and may be itself scratched by all those which follow it in the scale. Thus ten degrees of hardness are obtained between the softest mineral, which is talc (a mineral composed principally of magnesia), and the hardest—viz., the diamond.

These degrees are represented in the following table by the corresponding bers: they are as follows:—

Degree of hardness 1 — talc;
" " 2 — gypsum;
" " 3 — calcareous spar;
" " 4 — fluor spar;
" " 5 — apatite, or phosphate of lime;
" " 6 — feldspar;
" " 7 — quartz;
" " 8 — topaz;
" " 9 — corundum;
" " 10 — diamond.

If, therefore, the degree of hardness of a certain mineral is seven, we know it to be equal to that of quartz. The best way of testing the hardness of a mineral is to rub it on a fine hard file, in comparison with the minerals that constitute the scale.

Q. Upon what does the LUSTRE of a mineral depend?

A. On the *nature of its surfaces;* thus we distinguish minerals as having a *metallic lustre*, a *vitreous* or *glassy lustre*, a *waxy lustre*, a *pearly lustre*, and a *silky lustre.* Some minerals are also described as *resplendent*, *shining*, *glistening*, *glimmering*, and *dull;* those of earthy fracture are distinguished by the latter term.

Q. What is the STREAK of a mineral?

A. It is that colour which appears on *rubbing* or *streaking* a mineral on a *white body*, or on scratching it with a harder substance. The *streak* of a mineral is a very remarkable characteristic.

Q. What minerals possess TASTE?

A. Those only which are *soluble in water*, of which there are comparatively few.

Q. How is the CHEMICAL COMPOSITION of a mineral DETERMINED?

A. By *analysis*, or by *heat* and the use of the *blowpipe.*

Q. Does the FUSIBILITY of minerals VARY in any great degree?

A. Some fuse at a gentle heat in the *flame of a lamp;* others are fused only by the application of most intense heat. The products of fusion are also exceedingly multifarious, and serve to point out the character and composition of the mineral in question.

CHAPTER LXXI.

CRYSTALLOGRAPHY.

Q. What is CRYSTALLOGRAPHY ?

A. Crystallography is the science which *teaches the mathematical properties and classification of crystals.*

Q. What are the COMMON FORMS of CRYSTALS ?

A. They are of *all kinds* of forms: some very simple; others, exceedingly complex.

Q. Can crystals be produced by ARTIFICIAL MEANS ?

A. *Yes;* most of the *salts*, and other *substances soluble in water*, deposit crystals as they are subjected to evaporation. Crystals of sulphur may be obtained by cooling from a state of fusion; by evaporation of its solution; and by sublimation. Bismuth and some other metals assume the crystalline form in passing from the fluid to the solid state.

Q. By WHAT TERMS is the form of a crystal described ?

A. By *faces*, *edges*, *angles*, and *axes.*

Q. What is meant by the term FACES ?

A. The *plane surface* of a crystal.

Q. What is meant by its EDGES ?

A. The *lines formed* by the *union of two faces.*

Q. What is meant by its ANGLES ?

A. The *union of more than two faces.*

Q. What is meant by the term AXES ?

A. The *imaginary lines drawn through a crystal* for the purpose of *describing it geometrically.*

Q. What is meant by the SECONDARY FORMS of crystals ?

A. These are said to be produced by the *supposed truncations* of the *solid angles* or *edge* of the more regular forms. They are not of any regular form.

Q. How are TWIN CRYSTALS produced ?

A. These are produced by the *union* of *two or more crystals*, according to some regular plan.

Q. Are there ANY OTHER CLASSES of IRREGULARLY FORMED crystals ?

A. *Yes;* one termed *epigene*, and the other, *pseudomorphous;* the first is where a crystallised mineral has undergone a chemical change, without in any way changing its form; the second appears as if it

had been produced in moulds, resulting from the destruction of the original and the subsequent filling up with a new mineral of the space thus left vacant.

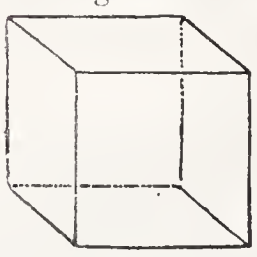
Q. Are these secondary forms ACCIDENTAL?

A. No; they may in *all cases* be *accounted for* on definite principles and laws.

Q. Are the DIFFERENT FORMS of crystals divided into CLASSES?

A. They are classified into *six* systems, namely; the *cubical;* the *prismatic* or *pyramidical;* the *rhombohedral* or *hexagonal;* the *prismatic* or *rhombic;* the *oblique;* and the *anorthic* or *doubly oblique.*

Fig. 250.



Q. Which is the FIRST SYSTEM?

A. That of the *cube*, which is at once the simplest and most regular. Fig. 250 shows the cube or square block.

Q. What are the CORNERS of the CUBE called?

A. The corners of the cube are called its *solid angles.* A solid angle or edge cut off so as to produce a new surface or plane is said to be *truncated.*

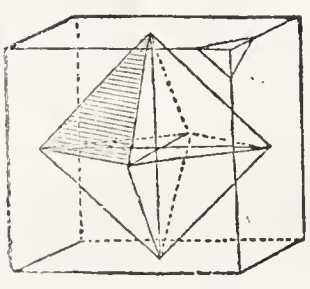
Q. How is the CUBE described?

A. It has *six faces, twelve edges, eight angles;* and faces, edges, and angles are all *equal.*

Q. What MODIFICATIONS can this form undergo?

A. Under what is called the *cubical system* is included—the *octahedron*, the *rhombic dodecahedron*, the *three-faced octahedron*, the *twenty-four-faced trapezohedron*, the *four-faced cube*, the *six-faced octahedron*, &c. &c.

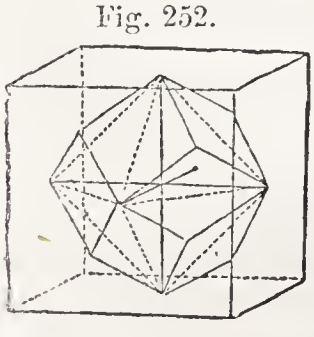
Fig. 251.



Q. Describe SOME of these forms.

A. The *octahedron* (fig. 251), has eight equal faces, has twelve equal edges, and six angles. The *rhombic dodecahedron* (fig. 252), is a solid with twelve equal faces, called rhombs; it has twenty-four edges, six four-faced solid angles, and eight three-faced solid angles.

Fig. 252.



Q. Is not the RHOMBIC DODECAHEDRON sometimes called by another name?

A. Yes; it is sometimes called the *garnatoedron*, on account of its form resembling the garnet.

Q. What OTHER FORMS are included in the FIRST SYSTEM?

A. The *hexatetrahedron* (fig. 253), consisting of twenty-four triangular faces; and the *trape-*

zohedron (fig. 254), consisting also of twenty-four faces, each of that form known as the *deltoid*, or *trapezium*.

Fig. 253.

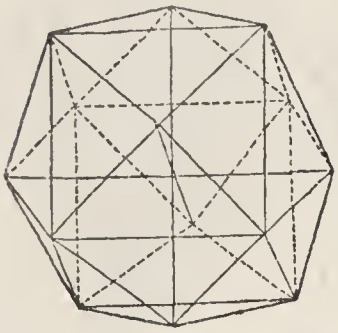
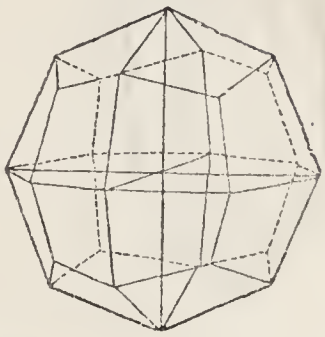


Fig. 254.



Q. What is the form known as TETRAHEDRON?

A. Its form is derived from the *twenty-four-faced trapezohedron*, by the development of half its faces. (*See fig.* 255.)

Fig. 255.

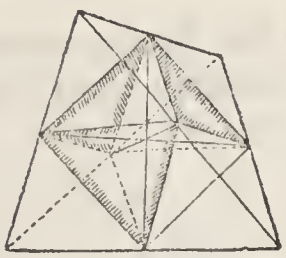
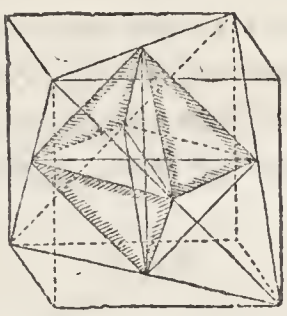


Fig. 256.



In the following figures are seen other forms belonging to the cubic system.

Fig. 257.

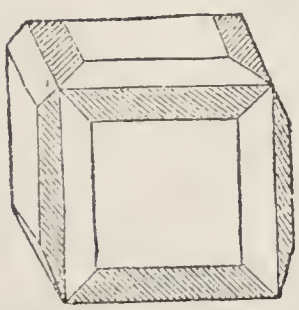


Fig. 258.

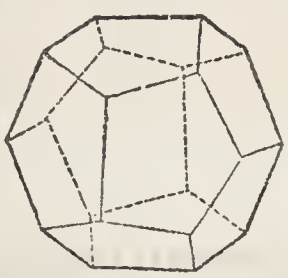
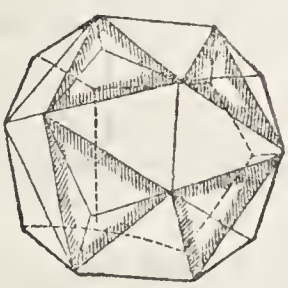


Fig. 259.



Q. Mention SOME of the MINERALS whose crystals occur in the form of the CUBE, or MODIFICATIONS of the CUBE.

A. Alum, bromine, copper, diamond, fluor, garnet, gold, iron, muriate of silver, sulphuret of cobalt, magnetic iron ore, platinum, sulphuret of iron, sal ammoniac, salt, silver, &c.

Q. What is the SECOND SYSTEM, or CLASSIFICATION, of minerals?

A. The *pyramidical*, or *prismatic*.

Fig. 260.

Q. As the cube is to the CUBICAL SYSTEM, what is the leading figure in the PYRAMIDICAL SYSTEM?

A. The *square prism* (fig. 260.) It has *six faces*, four of which are oblongs or rectangular parallelograms; the top and bottom are square; it has *twelve edges* and *eight angles*. *Modifications* of this form are seen in figs. 261, 262.

Fig. 261.

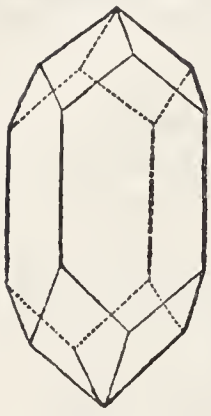
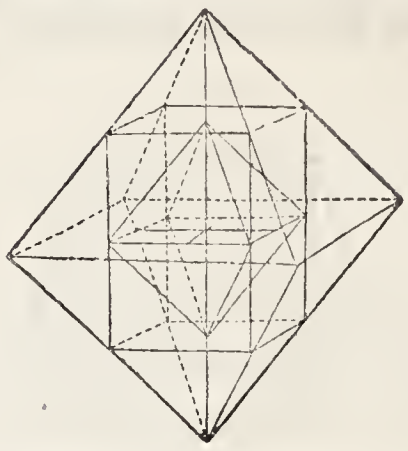


Fig. 262.



Q. What MINERAL CRYSTALLISATIONS are classified under this SECOND SYSTEM?

A. Among them are: braunite, calomel, gehlenite, pyramidical garnet, oxide of titanium, carbonate of cerium, tungstate of lead, tin, &c.

Q. What is the THIRD CLASSIFICATION?

A. The *rhombohedral* or the *hexagonal;* the former when its forms are derived from the *rhomboid* (fig. 263), the latter when derived from the *hexagonal prism.* (*See fig.* 264.)

Fig. 263.

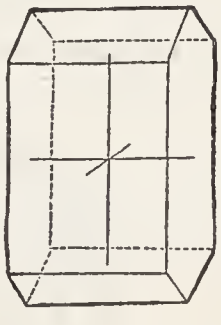
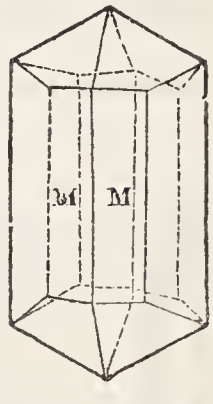


Fig. 264.

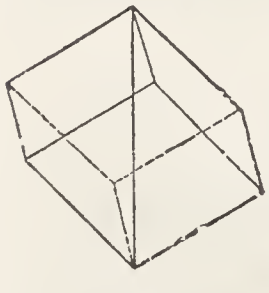


Q. Mention SOME of the MINERAL CRYSTALS belonging to this third system.

A. Antimony, arsenic, bismuth, calamine, emerald, graphite, nickel, arsenite of lead, nitrate of soda, quartz, tellurium, &c.

Q. What is the FOURTH SYSTEM, OR CLASSIFICATION?

Fig. 265.



A. The *rhombic* or *prismatic.* The rhomboid (fig. 265) has *six equal faces;* all of which are *rhombs* —namely, four-sided figures with equal sides and opposite angles; but the angles are not all equal. As in the case of the *cube*, this figure gives rise to numerous and complex variations. Some of these forms are indicated in figs. 266, 267, 268.

Q. Enumerate SOME of the CRYSTALLISATIONS included under this fourth division.

A. Sulphate of lead, carbonate of lime, sulphate of barytes, phosphate of iron, nitrate of potash, sulphur, topaz, &c.

Fig. 266.

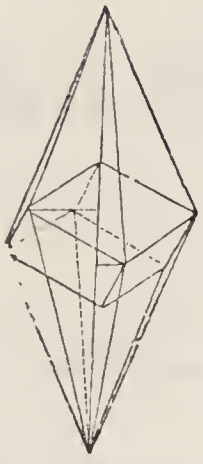


Fig. 267

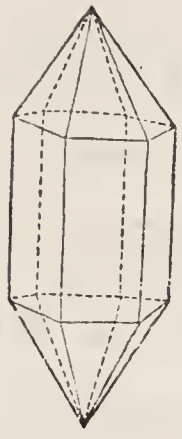
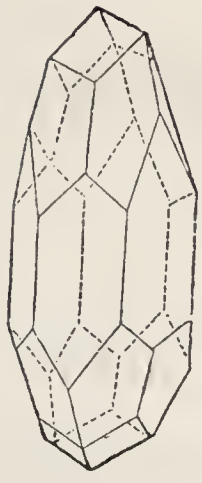


Fig 268.



Q. What is the FIFTH SYSTEM ?

A. That which is known a the *oblique*. Some of its modifications of form are indicated in the following figures.

Fig. 271.

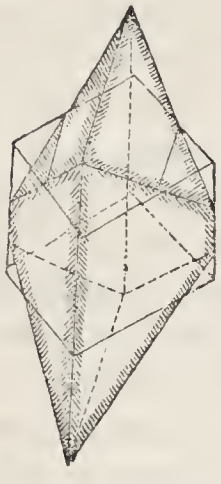


Fig. 269.

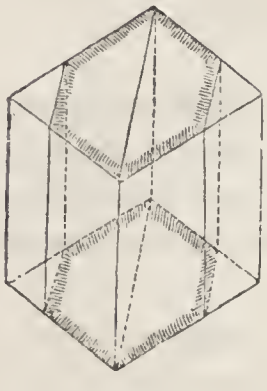


Fig. 270

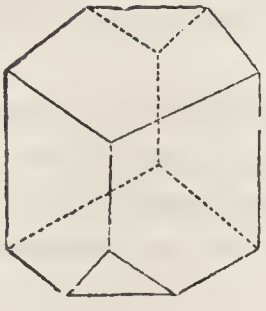


Fig. 272.

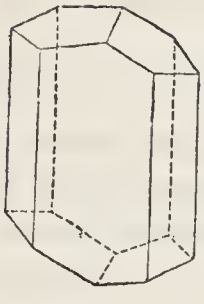
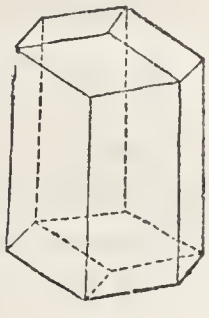


Fig. 273.



The substances included in this classification are felspar, glauberite, gypsum, red antimony, sulphate of lead, phosphate of copper, mica, &c. &c.

Q. What is the SIXTH CLASSIFICATION ?

A. The sixth classification is known as the *doubly oblique*, and sometimes the *anorthic*, from the want of symmetry in its form. In this division all crystals are included which cannot be put under any other classification. Figs. 274 and 275 represent forms of this system.

Fig. 274.

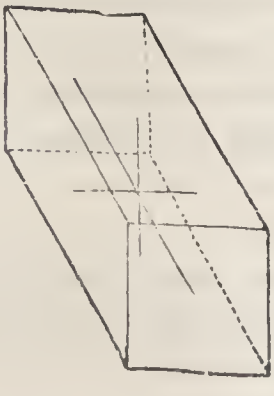
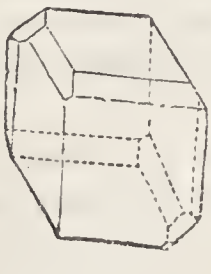


Fig 275.



GEOGRAPHY OF PLANTS AND ANIMALS.

CHAPTER LXXII.

DISTRIBUTION OF PLANTS.

Q. What is MEANT by BOTANICAL GEOGRAPHY?

A. That branch of *natural science* which treats of the *distribution* of *plants throughout the world*, and shows how the various parts of the earth's surface are characterised by *distinctive forms of vegetation.*

Q. Is VEGETATION found in ALL PARTS of the world?

A. Yes. But the *greatest varieties* are observable, not only in those direct and positive contrasts, such as are afforded by the plants of the arctic and tropical regions, but in varieties of a finer and more delicate character, which are still obvious to the naturalist.

Q. Is vegetation PECULIAR to the land ONLY?

A. The *waters* as well as the *land* exhibit an almost *endless variety of vegetable life.* Vast meadows of gulf weed float in the ocean, submarine forests exist in its depths, every marsh and pool has a sort of slime of peculiar character, and the bed and surface of rivers bear indications of vegetable existence.

Q. What SCIENTIFIC TERMS are employed in treating of botanical geography?

A. Two of the most common terms used with respect to the geographical classification of plants are *habitation* and *station.* By habitation is meant that particular part of our globe to which the plant in question is peculiar—where, in fact, the plant has its habitation—its home. By station is meant the peculiar nature of the locality, the character of the home as regards climate, soil, moisture, light, elevation above the sea, and other circumstances which affect the growth and full development of the plant.

Q. What is meant by VEGETABLE ZONES?

A. It having been ascertained that certain plants are only to be found in certain places, that is to say, that a peculiar species of vegetation distinguishes one part of the globe from another, naturalists have classified these divisions, and given them the name of *vegetable zones.*

Q. Into HOW MANY VEGETABLE ZONES is the earth divided?

A. Eight divisions called by this name are recognised, namely:—

1. The *equatorial zone*, chiefly remarkable for palms and bananas.
2. The *tropical zone*, of figs and fern trees.

3. The *sub-tropical*, of laurel and myrtle.
4. The *warm temperate zone*, of evergreens.
5. The *cold temperate zone*, of European trees.
6. The *sub-arctic zone*, of conifers.
7. The *arctic zone*, of rhododendrons.
8. The *polar zone*, including the various forms of Alpine plants.

Q. Then we are to understand that the GEOGRAPHICAL DISTRIBUTION of PLANTS is regulated by PARTICULAR LAWS, and that each PARTICULAR DISTRICT is distinguished by its OWN PECULIAR SPECIES of vegetation?

A. Such is, undoubtedly, the fact. The phenomena which control this appear to be *climate*, *humidity*, *light*, and *soil.*

Q. What are the EFFECTS of TEMPERATURE on vegetation?

A. The most luxuriant vegetation is in a great measure attributable to an *increased temperature;* thus, under the brilliant sun of the tropics, the variety and the beauty of the vegetation surpass all that is ever seen in the temperate zones. If, again, we contrast the beautiful productions of the temperate zones with those of the polar, nothing can be more evident than that the influence of temperature upon vegetation is most powerful.

Q. Does the MANNER in which a given amount of HEAT is COMMUNICATED at all DIVERSIFY the effects produced?

A. It does; as, for instance, in those districts where a long winter is followed by a hot, brilliant, but short summer, the vegetation is totally different from that of those other districts where the temperature is more equable. This is the case when the same amount of heat is the mean annual temperature of both.

Q. What are the EFFECTS of MOISTURE upon vegetation?

A. Moisture has a very marked and decided *effect* on vegetation. The characteristics of those plants which are more exposed to it than others is very different from those others; as, for instance, the deep valleys of the American rivers present a striking contrast to the American prairies.

Q. What INFLUENCE has the SOIL upon vegetation?

A. An influence the most *important.* Any ordinary agriculturist acquainted with the common principles of farming will be able to bear testimony to this fact, even in a small district. We have only to extend this evidence; what is true of one locality will be true of another; and if the artificial varieties engendered in soils produce such marked effects, what still more remarkable effects may be safely predicated of the varieties of soil which extend over the wide surface of the earth.

ATMOSPHERIC PRESSURE.—"Atmospheric pressure would at first seem only a very subordinate influence upon vegetation. But comparing Alpine vegetation with that of higher latitudes, which, from their situation, must have climates otherwise very similar, we shall be led to the conclusion that atmospheric pressure has its share in bringing about the diversity of plants; for, though analogous, the flora of the high north is by no means identical with that of the most elevated Alpine ridges over which vegetation continues to

extend. The influence of atmospheric pressure seems to be particularly evinced in the great, the prevailing number of Alpine species endowed with a volatile fragrance, which adds so much to the sweet and soothing influence of mountain rambles; whilst the northern species, however similar to those of the Alps, partake more or less of the dullness of the heavy sky under which they flourish."—*Hughes.*

Q. Has ELECTRICITY any INFLUENCE on vegetation?

A. The *rapidity of growth* seen in all vegetation after the thunderstorms of spring, shows that electricity has a marked influence on vegetable life. Light also exerts a wonderful influence, some plants thriving best in shaded places, others under the direct rays of light.

Q. Has the POSITION and FORM of a country any INFLUENCE of this kind?

A. The form of *continents*, their *mountain ranges*, the *mean level of their great plains*, all have an influence on vegetation; that of land on the coast also, or that of islands, differs materially from that of inland parts.

"However active," says a recent writer, "these physical agents may be, it would be very unphilosophical to consider them as the source or origin of the beings upon which they shed so extensive an influence. However powerful may be the degree of heat, be the air ever so dry or ever so moist, the light ever so moderate or ever so bright, alternating ever so suddenly with darkness, or passing gradually from one condition to the other, these agents have never been observed to produce anything new, or to call into existence anything that did not exist before. Whether acting isolated or jointly, they have never been known even to modify, to any great extent, the living beings already existing, unless under the guidance and influence of man, as we observe among domesticated animals and cultivated plants. This latter fact shows, indeed, that the influence of the mind over material phenomena is far greater than that of physical force, and thus refers our thoughts again and again to a Supreme Intelligence for a cause of all these phenomena, rather than to so-called natural agents."

Q. What are the CHIEF PRODUCTIONS of the tropical regions?

A. In the tropical regions vegetation is seen in the greatest luxuriance, the fullest energy, the most marvellous diversity, and most dazzling splendour. The grasses, which in our climate we only know under the humble forms they put on in our fields and pastures, rise into the elegant and majestic bamboo, to the height of sixty or seventy feet. The tropical regions furnish more than thirteen thousand species of plants. The *palm*, the *baobab*, the *sugar-cane*, &c., are remarkable; while *geraniums* of every kind, *myrtles*, *roses*, and other plants, are as *common* as weeds.

Q. What are the PECULIARITIES of Arctic vegetation?

A. In the polar and frozen regions life seems almost extinguished by the rigorous cold of a *perpetual winter*. A colourless and stunted vegetation, a few creeping shrubs, and endless plains covered with mosses and lichens, are alone beheld.

In the order of nature, and at the first approach, we cannot deny to the tropical regions a marked superiority. The most powerful spring of physical life, the most active source, that which surpasses all others, is the heat of that life-giving orb which the ancient nations, forgetting God, the only true Creator of all things, adored as the parent of Nature. But, in virtue of the spherical form of the earth, each district of the surface receives an unequal portion. Slanting, scattered, and feeble in the regions near the poles, but assuming more strength and falling thicker in the middle regions, in those of the equator only they gain all their intensity, all their splendour.

Q. What are the CHARACTERISTICS with respect to vegetation of the temperate regions?

A. Those countries which approach nearest to the torrid zone have a climate which in many particulars resembles it; as you advance farther and farther north it becomes colder; those countries which lie near to the polar circle are almost as cold as those within it. But the peculiarities of the temperate regions are seen in evergreen woods, in rich grassy meadows, in varieties of trees, and many kinds of grain and fruit.

FOOD PLANTS.

Q. What is meant by FOOD PLANTS, and what are their PRINCIPAL VARIETIES?

A. Food plants are those plants which form the vegetable part of the food of man; they are barley, oats, rye, wheat, millet, olive, date, palm, banana, rice, maize, potatoes, arrow-root, sugar, coffee, tea, wine, cocoa, &c.

Q. Are these food plants WIDELY DISTRIBUTED?

A. They *are;* the *staple* food of one country differing very widely from that of another. Barley is one of the most widely spread, bein

Fig. 276.

BARLEY.

cultivated from the limits of Lapland to the heights beneath the equator. In the East barley is the staple grain for making bread.

In the above illustration (fig. 276), A represents the common barley, B the fan barley.

Fig. 277.

OATS.

Q. What GRAIN is employed as BREAD CORN in the north of Europe?

A. *Rye* and *oats* form the principal bread corn of Russia, Finland, Norway, and Sweden. Oats will grow in soils which will bear neither

Fig. 278.

VARIETIES OF WHEAT.

A, the giant species; B, the common winter wheat C, the bearded wheat; D, the Talavera wheat.

wheat nor *barley*, and in situations not adapted to other grain. In the hilly districts of Scotland and Derbyshire it is almost the only *grain cultivated.*

Q. Where is wheat PRINCIPALLY GROWN?

A. Wheat is cultivated extensively throughout *Great Britain*, *France*, *Germany*, and towards the *East;* it is also cultivated to a great extent in *North America.* It flourishes not only in our temperate climate, but in the extremities of heat and cold. It is found in *Lapland*, and was seen by Humboldt, under a burning sun, growing with *coffee*, *plantains*, and *sugar-canes.* It is the plant most necessary to mankind, and, therefore, most widely diffused.

Q. What is MAIZE?

A. Maize, or Indian corn, known also by the name of Turkey corn, is the *largest and handsomest* of all the grasses cultivated for food. When full grown, it attains a height of from five to six feet; while its broad leaves, springing from its thick, straight stem, and its elegant spike of flowers at the summit, present a form which is rarely surpassed. Next to rice, it supplies food to the greatest number of the human race. It forms the staple crop in North America, where the farmers make it answer a great number of purposes besides supplying their families with bread. It is also cultivated in Mexico, and, to a limited extent, in Germany and France.

Q. Is rice EXTENSIVELY CULTIVATED?

A. Yes: it is *the staple food of millions of people* in the East, including those of the Indian Peninsula, China, Japan, and the East Indies.

Q. What is the MOST USEFUL FOOD PLANT of the tropical regions?

A. The *palm tree.* It yields the cocoa-nut, the date, oil, sago, sugar, and a juice which is easily converted into wine; while its leaves, if boiled, form an excellent substitute for a *cabbage.*

Palm trees are now found growing native in Europe, Asia, Africa, America, and Australia; but, with the exception of two dwarf species, the *chamærops humilis*, in Europe, and the *chamærops palmetta*, in North America, they are all denizens of tropical lands, and their region may be considered as bounded by the thirty-fifth degree of northern, and the fortieth of southern latitude. Nevertheless, one species at least, the date-palm, has been so far naturalised in certain localities of Southern Europe, especially Andalusia and Valencia, that it grows to maturity and produces fruit—though far inferior to the dates of Africa. The greatest authority on palm trees is Herr Von Martius, a German botanist, who, with a view of studying their characteristics, devoted three years to a travelling excursion in Brazil—a region more rich in palms than any on the face of the globe. This botanist considers that there are existing at this time upwards of a thousand species of palms. If the opinion be correct, future botanical explorers have a rich field of investigation yet untrodden, inasmuch as no more than 175 species have yet been individualised and described: of these, 119 belong to South America, 42 to India, and 14 to Africa. It is a very curious fact, not satisfactorily accounted for, that the cocoa-nut palm will not flourish at any great distance from the sea: hence, islands are best adapted to their culture, and in Central Africa there are none. Botanists are inclined to refer this predilection for the sea-shore to the tendency which these trees have to take up salt; and the idea is partly confirmed by the known fact of their partiality, if the term may be allowed, for alkaline food.

Q. What is the BANANA, or PLANTAIN?

A. This plant, a native of Southern Asia, is now generally found in all *tropical climates.* The fruit is very valuable, and at the same time economical. The same space which will bear *five hundred pounds* of potatoes will bear *twenty-two thousand pounds* of bananas.

Q. Mention SOME OTHER FOOD PLANTS, and the COUNTRIES to which they belong.

A. The *bread-fruit tree* is found among the *Friendly* and *Carolina Islands;* the *yam* is cultivated throughout the inter-tropical zone of the *Old* and *New Worlds;* the *potato* is a native of *Chili*, and was introduced into Britain by Sir Walter Raleigh, in the reign of Queen Elizabeth; the *sugar-cane* extends all over the regions of the *torrid zone; coffee* is a native of *Africa*, and was introduced from Ethiopia to Arabia and the West India Islands; *tea* is cultivated throughout *China* and *Japan.*

Q. Are not some species of plants confined to VERY LIMITED DISTRICTS?

A. They *are:* as, for instance, the *Irish yew*, which appears to grow naturally nowhere but in Ireland. The *Scotch fir*, on the contrary, is met with in various other regions having a similar climate.

Q. Does not the VARIATION in VEGETATION agree with the degree of latitude in one direction, and the elevation above the sea level in the other?

A. It *does.* The natural productions of any given latitude bear a striking resemblance to that at a given height above the sea level. Thus polar vegetation and that of lofty mountains is almost the *same.*

"Changes in vegetation, similar to what are found in passing from the equator to the poles, occur from the base to the summit of mountains, which is strikingly exhibited in Etna, the Peak of Teneriffe, the Alps, Pyrenees, Andes, and Himalaya mountains. Each plant has its limit in elevation, as in latitude. On Teneriffe Humboldt found vegetation in about five zones; the region of vines, from the shore to an elevation of about 640 yards; the region of laurels; the region of pines, from 1920 to 2770 yards; then follows a zone characterised by a species of broom; then the region of the grasses. Above these are a few cryptogamic (flowerless) plants."—*Reid.*

Q. How are the VARIETIES of VEGETATION distributed over the wide expanse of the globe to be ACCOUNTED FOR?

A. Humboldt makes the geography of plants part of the theory of the earth; and, including the whole in one intelligent glance, shows that the distribution of plants on a *larger scale*, as well as on a *smaller scale*, depends on the *physical qualities* of our earth.

CHAPTER LXXIII.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS.

Q. What is the OBJECT of ZOOLOGICAL GEOGRAPHY?

A. Zoological geography treats of the *distribution of animals, as they at present exist*, as well as the varieties of animal life considered in relation to external circumstances.

Q. In what does it DIFFER from ZOOLOGY?

A. Zoology describes the animals of our world in their *distinctive characters;* zoologic geography teaches their place on our world, the particular species which are common to particular countries, and shows us that they, as well as plants, have their natural *stations* and *habitations.*

Q. What is meant by the term FAUNA?

A. The term fauna is applied to *all species of animal life*—both of land and water—which belong to a particular country or district. Such a collection is called the *fauna* of the country, as the plants peculiar to that country are called its *flora.*

Q. What PRINCIPAL DIVISIONS are usually made in describing the distribution of animal life?

A. The fauna are distributed into three great divisions: the *temperate*, *arctic*, and *tropical.*

Q. Does the ANIMAL LIFE of any country, or district, depend on the VEGETABLE PRODUCTIONS of that district or country?

A. It *does to a certain extent;* but to a *certain extent only.* The vegetable productions are mainly dependent on climate, the animal life is less dependent on it, as the fauna of any locality includes not only the terrestrial animals, but those of the sea.

Q. Has not the FOOD of animals an IMPORTANT BEARING on their distribution?

A. The *herbivorous* (herb-eating) animals are naturally confined to those localities where such vegetation is abundant. The *carnivorous* (flesh-eating) animals have a wider distribution, as they can find their food in all parts. The same remarks apply to birds of prey and to *grainivorous* (grain-eating) birds.

Q. The ocean being UNIFORM in its nature, are not the animals which dwell there all of ONE CLASS, or all classes in all places?

A. No. The animal life of the ocean is *distributed* into particular *localities*, as much as are the terrestrial animals or the vegetation of the different zones. In order rightly to understand this, we must remember that the *coast line* of the earth, and not the open *sea*, is to be considered in the position of local *fauna.*

Q. Does the DEPTH of the water affect the distribution of AQUATIC ANIMALS?

A. Yes; the fishes generally found near the surface differ from those which live at a considerable depth. Their colour, in particular, is obviously different.

Q. Are not SOME ANIMALS found only in ONE LOCALITY, while others are distributed in GROUPS in similar climates?

A. Yes; as the Irish *yew tree* belongs essentially to the flora of Ireland, so the *kangaroo* is peculiar to Australia.

Q. Do the animals which are found at very great distances apart bear an EQUAL DISPROPORTION in form and character?

A. No; not as a rule. Very similar faunas are often very widely separated. Very similar faunas are found in Europe and in the United States of America.

"Animals are endowed with instincts and facilities corresponding to the physical character of the countries they inhabit, and which would be of no service to them under other circumstances. The monkey, which is a frugivorous animal, is organised for living in the trees, from which he obtains his food. The reindeer, on the contrary, whose food consists of lichens, lives in cold regions. The latter would be quite out of place in the torrid zone, and the monkey would perish with hunger in the polar regions. Animals which store up provisions are all peculiar to temperate, or cold climates. Their instincts would be uncalled for in tropical regions, where the vegetation presents the herbivora with an abundant supply of food at all times."—*Hughes.*

Q. What are the CHARACTERISTICS of the FAUNA of the TEMPERATE REGIONS?

A. The temperate regions abound with *terrestrial animals*, which, if less in size and brilliancy of appearance than those of the tropics, are nevertheless infinitely superior in form, life, and colour to those of the arctic zones. There is a great similarity existing between the fauna of the temperate regions, both in the northern and southern hemispheres. Of these we may mention the *horse*, *deer*, *ox*, *hog*, *squirrel*, *hare;* many of the birds are identical; and among fishes may be counted, *trout*, *sturgeon*, *pike*, *cod*, *mackerel*, *herring*, &c.

Q. Are there not animals PECULIAR TO AMERICA which are not found in Europe?

A. Yes; in the temperate regions of America are found the *opossum*, some species of *moles*, and the species of tortoise known as the *snapping turtle.*

Q. What species are PECULIAR to the temperate regions of Europe?

A. The *wild boar* and the *mouse.*

Q. Do not CONSIDERABLE CHANGES take place in the fauna of the temperate regions?

A. The variations of climate produce many *apparent changes* in the animal world, especially among insects and some species of birds.

Q. Are there not SOME SPECIES of animals which are found extending from one extreme of the temperate zone to the other in both the American and European continents?

A. Such is the case, as we find different kinds of *birds of prey*, with the *flying squirrel*, the *deer*, the *bison*, &c.

Q. What are the CHIEF PECULIARITIES of the animals of the tropics

A. They are distinguished by their *numerous variety* and *brilliant colouring.*

Q. Does this variety and beauty extend to ALL CLASSES of animal life?

A. Yes; both *terrestrial* and *aquatic* animals, *birds* and *insects*, are remarkable for an increased size and brilliancy.

Q. Mention SOME of these animals.

A. In the tropical regions are the largest species of *monkeys*, the *elephant*, *hippopotamus*, *chiropotamus*, *giraffe;* the largest of the cat tribe, such as the *lion*, *tiger*, &c. *Crocodiles* and huge *tortoises* are counted amongst its reptiles; *parrots* and *macaws*, amongst its birds. Above three hundred species of *humming birds*, and islands covered with coral reefs formed by the *polypi.*

Q. Are there not MANY VARIETIES in the TROPICAL FAUNA?

A. The animals distributed over what are known as the tropical regions vary in different localities: thus, in *Brazil* we find an im-

mense number of insects and enormous reptiles, with many peculiar varieties of humming birds.

Q. What are the CHIEF CHARACTERISTICS of the animals belonging to the ARCTIC or POLAR REGIONS?

A. Their principal and most prominent characteristic is *uniformity.* The species are *few*, but the individuals of each species are very *numerous:* this is especially remarkable with the birds and fishes. Among the former are a large number of *gulls*, *cormorants*, *petrels*, and other aquatic birds; among the latter is the *salmon.* The *mammalia* consist of the white bear, the moose, the rein-deer, the musk-ox, seals, lemming, and the whale: the whale, indeed, is the most important.

THE RACES OF MAN.

Q. While animal and vegetable life, of a peculiar and distinctive character, marks the different localities of the globe, is not MAN the SAME in every country and climate?

A. The organisation of animal and vegetable life is adapted to particular and distinct climates and country; but *man*, the *chief being* in this world—the lord of creation,—has physical capacities which enable him to dwell in *every climate*, *soil*, and *situation.*

Q. Is there, then, NO VARIETY in the HUMAN RACE?

A. On the *contrary*, there are very great *varieties* in the human family, although it is perfectly identical, and in every important particular essentially the same.

Q. Has this identity of the human race ever been DISPUTED?

A. Notwithstanding the direct testimony of Scripture that we are the *offspring of common parents*, it has been asserted that some of the people of uncivilised countries are so low in the scale of intellect as to be really an inferior race. Such has been said of the *Negro* and native *Australian.*

Q. Is there ANY TRUTH in such an assertion?

A. None whatever. Man is the same everywhere, and only requires the facilities afforded by civilisation and refinement to develop those faculties the non-existence of which has been so boldly asserted.

Q. How is the human family DISTINGUISHED?

A. Naturalists commonly divide it into *races.*

"The expression races, however, applied to man, involves something abhorrent from his high uplifted spirit, and debasing to his native dignity. This diversity of races among men no one ought to exaggerate in a manner so as to raise doubts as to the identity of their origin; for, according to a general organic law, which, indeed, is allowed to hold good in the natural history of animals, races capable of a prolific union must be considered of the same origin, and, in constitution, the same species. Even the apparent chaos of different languages may be classed into kindred families, which, though separated by the distance of half the globe, seem still very closely allied. Of these different families of tongues, the first and most eminent are those which, by their internal beauty, and the noble spirit breathing through them, and apparent in their whole construction, denote, for the most part, a higher origin, and divine inspiration; and, much as all the languages differ from each other, they appear, after all, to be merely branches of one common stem.

When man had once fallen from virtue, no determinate limit could be assigned to his degradation, nor how far he might descend by degrees, and approximate even to the level of the brute."—*Schlegel.*

Q. Into HOW MANY RACES has the human family been divided?

A. The three leading divisions are the *Caucasian*, the *Mongolian*, and *Ethiopian*, to these may be added the *Malayan* and *American.*

Fig. 279.

THE CAUCASIAN RACE: APOLLO BELVEDERE.

Q. What nations are comprised under the CAUCASIAN RACE?

A. It includes the *European* nations, with the exception of the *Lapps* and *Finns.* It also occupies some part of Africa and Asia.

This class is, indeed, very extensive, including the ancient and modern Europeans and Western Asiatics, such as the Assyrians, Babylonians, Medes, Persians, Scythians, Parthians, Arabs, Jews, Syrians, Turks, Affghans, and Hindoos. To these must also be added the European colonists who have settled in America and other parts of the world. Our engraving (fig. 279) shows the finest specimen of the race, taken from the ancient sculpture of the Apollo Belvedere.

Q. What are the DISTINGUISHING CHARACTERISTICS of the race?

A. The complexion is *usually fair;* the face oval; the forehead broad; the hair of various colours, soft and flowing, or slightly curled; the eyes varying in colour; the nose rather thin and straight; the mouth rather small; and the chin full and round. The whole figure and aspect of the race is handsome and agreeable.

Q. What are the CHARACTERISTICS of the MONGOLIAN race?

A. The *head is squarer* than that of the Caucasian; the nose flat, with distended nostrils; the eyes drawn up at the outer corners; the

cheek bones projecting; the complexion of a yellowish, dirty hue; and the height of the figure rather shorter than that of the European.

Fig. 280.

THE MONGOLIAN RACE : A CHINESE.

Fig. 281.

THE MALAYAN RACE : A TAHITIAN.

Q. Over WHAT COUNTRIES does this race extend ?

A. It *includes* the Lapps and the Finns, with some of the Hungarians in Europe; all the Asiatics north and east of the Caspian Sea; the Chinese and Japanese; and the Esquimaux who reside on the shores of the polar sea, in America and Greenland.

Q. What are the PHYSICAL PECULIARITIES of the MALAYAN race ?

A. The Malayan race has the upper part of the head slightly narrowed; the forehead arched; the face narrower, and the features more prominent than those of the Negro; the complexion brown; and the hair black and abundant.

Q. What DISTRICTS are included in this division ?

A. The islands of the *Indian and Pacific Oceans.*

Q. What are the CHARACTERISTICS of the NATIVE AMERICAN races ?

A. They approach *in many respects* those of the Mongolian race. The face is broad; the features prominent; the skin red, or copper colour; the hair dark. This division includes the whole of the native American tribes.

Q. Has not the NATURAL SEPARATION of the continent of America into two parts AFFECTED the DISTRIBUTION of the race ?

A. It has led to the subdivision of the American race *according to their position* in the North American nations; among which are

the Iroquois, the Cherokees, the Sioux, the Columbians, and the Californians; and the South American nations, including the Peruvians, the Patagonians, the Caribbees, &c.

Fig. 282.

THE AMERICAN RACE: A PATAGONIAN.

Fig. 283.

THE ETHIOPIAN RACE: A NATIVE OF MOZAMBIQUE.

Q. What are the CHARACTERISTICS of the Ethiopian race?

A. A black skin, black woolly hair, low forehead, projecting jaws, thick lips, and a retreating chin. The type of the race is fully seen in the Negro. To the Ethiopian race are connected the Hottentots and Kaffirs. To the same class are referred the Negroes of Oceanica, who are distinguished from the African race in several particulars, and who, under the name of Papouas, are the native inhabitants of Australia, New Caledonia, Van Diemen's Land, New Guinea, &c.

Q. What GREAT FACT is established by a CLOSE EXAMINATION of the DISTINCTIVE PECULIARITIES of the races of man?

A. That, notwithstanding all the *variations of colour and appearance* which are observable in the different races of man, the most positive identity exists among them all, and that GOD HATH MADE OF ONE BLOOD ALL NATIONS OF MEN.

INDEX.

Absolute humidity, 213
Absorption and conduction, 123
of heat, examples of, 123, 150
Accidental colour, 248
Acetic acid, 391
Acid, every fat contains an, 408
Acids, 306
dissolve, 136
produced from plants, 391
Aconitine, 391
Acoustics, science of, 73
Acorn, 444
Actinism, what is, 261
Action and reaction equal, 30
Adhesion, definition of, 7
Adjective colour, 431
Aerolites, 223
ignite, why, 225
Affinity, 176
force of, 305
Agassiz, Prof., 472
Aggregation, state of, 5
Agriculture and rural economy, 439
Air, a bad conductor of heat, 103
a conductor of lightning, 279
always saturated, where, 213
atmospheric, 59
how heated, 110
how made cold, 186
of what composed, 185
chamber, 130
change in, how diminishes the heat of the body, 124
circulation of, through a bed at night, 174
colour of, 59
currents of, in a room, 169
density of, law regulating, 162
influence on evaporation, 152
more uniform at night than by day, 79
does not radiate heat, 117
drawn towards the fire, 172
appears blue, 59
effect of rarefaction, 171
effects of cold on, 186
earth's motion on, 189
heat on, 186
elasticity of, 60
electrified, when, 275
Air exists in water, 313
expanded by heat, 128
expansion of, 128
heated, influence upon the human system, 127
Sir Joseph Banks's experiment, 127
hot as the human body, 125
how caused to escape from the lungs, 64
how heated, 110, 185
impenetrable, 59
in an apple, 129
in cities less pure than in the country, 327
in contact with the earth, why colder, 115
in motion absorbs heat quickly, 124
in spring, why damp and cold, 95
in water, 61
its electricity varies, 275
motion of, tends to abstract heat, 110
moist, most transparent, 203
not heated by sun's rays, 110
necessary for production of sound, 63, 74
not invisible, 59
porous, 59
rarefied, 60, 186
previous to a storm, 63
rarity of, on high mountains, 63
seeks an equilibrium, 191
refractive power of, 244
vibrations of, produce sound, 73
waves, nature of, 77
what composed, 185
weight of, 60
compared with water, 61
where of uniform temperature, 118
why quiet before a tempest, 79
Alabaster, 372
Albumen, 404
vegetable, 394
Alchemists, 307
Alcohol, 396
and ether dissolve oil, 175
and water readily unite, 305
boiling point, 93
Ale, porter, &c., why froth, 67
Alkali, 306

Alkali metals, 369
Alloy, 367
Alluvium, 464
Altitude of shooting-stars, 224
Alum, 177
Aluminum, 373
Amber, 267
  electric properties of, 267
Ambergris, 414
Amalgam, 368
Ammonia, 320
Amorphous bodies, 177
Amethyst, 524
Anemometer, 190
Angle of incidence, 236
  of reflection, 236
Animal bodies, temperature of, 99, 100
  heat, cause of, 352
  life distinguished from vegetable, 404
  life, development of, 500
  odours, 414
  organisation, 404
Animals and plants, distribution of, 100
  peculiarities of, occasioned by temperature, 100
  Arctic, have white fur, 123
  flesh of old, tough, 405
  living deep in the ocean, 61
  what varieties possess the greatest muscular power, 41
Annealing, explanation of, 184
Annual plants, 452
Antimony, 289
Antiseptics, 403
Apple, why falls to the ground, 10
Aquatint, 437
Arago, his experiments, 91, 260
Arch, abutment or spring of, 52
  application of, in the human structure, 52
  strength of, 52
  what is an, 51
  when invented, 52
Architecture, definition of, 48
  orders of, 52
  origin of the different varieties of, 48
  useful art, 54
  definition of, 48
Area of a body, 2
Argand lamp, 343
Argillaceous rocks, 464
Arms and legs, levers of the third kind, 36
Arsenic, 385
  poisoning with, 385
Arterial blood, 352
Artesian wells, 520, 521
Artificial diamonds, 325
  light, 258
  how obtained, 258
  of what colours composed, 258
Artillery, effective distance of, 46
Arts, strength of materials used in, 47
Assafœtida, 416
Atmosphere, 185
  charged with electricity, 274, 275
  height of, 60
  pressure of, 61, 150, 167
  renewal of, 146
  thickness of, necessary, 247
  weight of the whole, 61
Atmospheric air, elements of, 59, 317
  engine, 167
Atom, definition of, 2
Atomic condition of matter, Newton's belief, 2
Attraction between particles of bodies, 6
  capillary, definition of, 22
  cohesive, 6
  definition of, 6
  of the earth, law governing it, 8
Aurora borealis, 226
Aurora does not affect the weather, 228
  not local, 226
  where seen, 226
Auroras, appearance of, periodical, 226
  more frequent in winter, 226
  occur in daytime, 226
  their use, 226
Avoirdupois weight, definition of, 16
Axles of railroad carriages, why liable to break from long-continued usage, 183

Baconio, his voltaic pile, 284
Ball, distance thrown by a twenty-four pounder, 44
  elastic, does not rebound from a pane of glass, 30
Balls, elastic, rebound when, 30
Ball fired from a cannon, why not for ever move, 8
Ball-lightning, 277
Balloon, how inflated, 130
Balloons, 130, 311
  ascend, why, 10, 130
Balusters, definition of, 54
Barilla, 369
Barium, 371
Bark adapted as a covering for trees, 106
Barley, how converted into malt, 398
Barometer and thermometer, 72
  cause of its changes, 196
  effect of heat and cold on, 73
  invention of, 70
  mercury in tube of, convex, 24
    rises in fair weather, 72
    sinks in foul weather, 72
  principle of, 70
  tube left open, why, 72
  rules for observing by, 71
  use as a weather-glass, 70
    for measuring heights, 70
    on land, limited, 71
  varies most, when, 72, 196
  wheel, construction of, 71
Base in chemistry, 306
  of a column, 56

Base of support for the human body, 13, 15
Battery, galvanic, 253
poles of, 284
Beam, bent in the middle, liable to break, 48
Beasts, why covered with wool, hair, &c., 104
Bed, circulation of air through the coverings of, 174
Bell, cracked, sound of, 78
made to vibrate, how, 78
metal, 75, 368
Bells heard farther at one time than another, 78
Bellows, explanation of the action of, 65
Biennials, 452
Birds do not fall from their perch when asleep, why, 36
feathers of pinions and tail strongest, 29
fly, why, 29
notes of, vary, 83
of prey see very far, 254
only one sex sings, 83
sing louder than man, 83
stretch out their necks in flying, 29
whistle rather than sing, 83
Bituminous, 497
Black absorbs heat, 125
lead, why used for blackening stove-pipes, 113
not a colour, 248
Bladder, inflated sound produced by the bursting of, 87
Blankets and woollens made with a nap, 104
feel warm, why, 104
Blocks, pulleys on board ship, 38
Blood, circulation of, how affected by friction, 97
Blood-heat, definition of, 93
Blowers help to kindle a fire, 173
Blowing food cools it, 110
force exerted by the chest in, 84
Blowpipe, 311, 312
Blue, why sky appears, 248
Boats, life, how prevented from sinking, 21
Bodies, natural, classes of, 3
Body, area of, 2
cool, becomes heated, how, 101
definition of, 1
figure of, 2
heated, becomes cool, how, 101
hot and cold at the same time, 89
position in which it rests, 11
qualities or properties of, 1
size of, 2
volume of, 2
Boiler, best form of, 162
Boilers, bursting of, accounted for, 163
liable to break, when, 137
of a liquid, what is, 147, 148
of thermometer, 140
Boiling water bubbles, why, 148
swells, why, 147
Bomb-shells, construction of, 46
Bones hollow and cylindrical, 47
Book, water, oil, &c., spilled upon, 24
Bottles, containing ale, cider, &c., liable to burst, 67
gurgle when liquor is poured out, 67
Boulders, 464
Brandy, 398
Brass, 367
Brass wire, how liable to change, 183
Bread, 457
becomes stale, why, 151
not bake well in polished pans, 123
Breath visible in winter, 209
Breathing difficult on high mountains, 63
on glass dulls it, 209
operation of, 62
Bricks, children of Israel used straw in the manufacture of, why, 51
of Chicago, why yellow in colour, 51
red, when burned, 51
Brimstone, 356
Brine, for pickling, strength of, ascertained, 20
Britannia metal, 368
Brittleness, definition of, 8
Bronze, 368
Broth cooled by blowing, 110
by convection, 110
by exposure to the air, 110
Bubbles, in a cup, follow the spoon, 10
in a cup of tea, 10
origin of, 4
Budding, 450
Building, essential parts of, 48
Bulb of plants, 452
Bullion, 384
Burning-point, 330
glass, 245

Cabbage very nutritious, 407
Calcareous manures, 442
Calm in the vortex of a hurricane, 196
Calms, 196
Calomel, 383
Caloric, definition of, 90
distribution of, 90
Calyx, 455
Camera-obscura, how formed, 263
Camphine, 411
Candle burns, how, 341
tallow, when fired from a gun penetrates a board, 25
Candles, image of, reflected in the windows, 237
several reflections produced, how, 237
Cane-sugar, 390
Cannon, effect of continual firing, 183
Cannon, recoil of, 44
varieties of, 46
Capital of a column, 56

Capstan, description of, 37
Capsular fibres, 418
Carbon and its compounds, 322
Carbonate of lime, 327
Carbonic acid, in the air, 326
chief sources of, 327
fatal to life, 326
gas, 325
of close rooms, how generated, 326
weight of, 330
Carbonic oxide, 329
Carboniferous or coal formation, 494
Carbonisation of wood, 157
Carburetted hydrogen, 345
Carcel, or mechanical lamp, 343
Carding, 427
Carnivorous animals do not perspire, 355
Carpets, Brussels and Wilton, 430
Carriage, high, liable to be overthrown, 13
Caseine, 406
Cask, phenomena of liquor flowing from, 65
Cast iron, 378
Cataract, cause of, 256
Cat, fur of, sparkles when rubbed, 270
Caverns, famous for echoes, 85
Caves, sound louder in, than on a plain, 80
Ceiling, limit of height for speaking, 86
Cellars cool in summer, 106
warm in winter, 106
Cellular tissue, 445
Cements and mortars, composition of, 50
Cement, definition of, 50
hydraulic, definition of, 50
Centimetre, definition of, 18
Centrifugal force, definition of, 26
Chair, person rising from, bends over, 11
Chalybeate, 312
Champagne sparkles, why, 68
Charcoal, 322
black, why, 246
fire hotter than wood fire, 323
Chemical action, a source of heat, 94
forces and agencies, 303
analysis, 308
attraction defined, 305
forces and agencies, 303
Chestnuts, crack when roasted, 129
Chimney-cowl, use of, 173
Chimneys, draught of, on what depends, 172
first used in England, 174
of manufactories, why made high, 173
raised high above a roof, 173
long, apt to smoke, 130
smoke, remedy for, 172
sometimes smoke, why, 172
Chinese discovered the properties of the magnet, 294
Chladni, his theory, 226
Chloride of lime, 360
Chlorine, 360
Chocolate, 393
Choke-damp, 327
Cinders lighter than coals, 334
Circuit, galvanic, 284
Cirro-cumulus clouds, 206
Cirro-stratus clouds, how produced, 206
Cirrus clouds, 204
Cleavage of a mineral, 525
Clock and watch, difference of, 32
common, 31
slower in summer than in winter, 138
Clothes, fine, warmer than coarse, 107
Clothing, loose, warmer than tight, 104
use of, in winter, 103
Clouds, 199
affect the wind, 189
around mountain peaks, 204
cirrus, 204
cirro-cumulus, 206
cumulus, how imitated, 205
dissipated suddenly, 232
distance of, 200
electricity of, 210
float, why, 200
higher on a fine day, 199
illustration of, 238
modifications of, 200
motion of, affected by electricity, 202
not always the same colour, 201
prevent the radiation of heat, 115, 201
red in the morning, 201
in the evening, 202
size of, cirro stratus, 206
cumulo-stratus, 207
stratus, how produced, 205
variety in, 200
Coal, 158
amount of, mined in Europe, 499
bituminous and anthracite, 497
fields of England and Wales, 498
floors and beds, 495
formation, classification of, 494
mines in Great Britain, 498
in America, 499
occurs in strata, 494
relative amounts of production, 499
shells and fossils, 497
sigillaria, 496
stigmaria, 497
varieties of, 322
vegetation of, 496
Cocoa butter, 393
Cocoas, 393
Cocoon, 426
Coffee, rule for roasting, 393
Coke, 323
Cold, greatest natural, 92
what is, 89
Colour, accidental, 248
complementary, 75
cause of, 247
definition of, 247
influence of, on radiation, 114

Colour of animals in arctic regions, 250
Colours, effect of contrast between, 251
law of the harmony of, 251
of animals suited to their habits, 250
of plants and animals on the globe, 250
optical effect of, 251
primary, 242
vegetable, by what rays of light most affected, 265
warmest for dresses, 125
Columns, Corinthian, 53
Doric, 52
Ionic, 53
Combustion, 230
respiration and nutrition, 330
Compasses, how constructed formerly, 343
Complexions, effect of colours on, 300
Composite order of architecture, 53
Composition of aerolites, 223
Compost, 493
Compounds of nitrogen, 317
Compressibility, definition of, 3
heat produced by, 99
Compression, definition of, 99
Concave and convex, definition of, 292
Concave mirror, 275
Concord and discord, 82
Condensing steam-engine, 159, 160
Conduction of heat, 101
Conductor, lightning, influence of, 279
its use, 279
Conductors do not attract lightning, 280
how productive of harm, 279
of lightning, 279
pointed, 279
Conglomerate, 463
Constant winds, 190
Contact, absolute, non-existence of, in matter, 3
Convection, meaning of, 108, 185
Cooling, law of, 109
Cooper, why heats his metal hoops before placing upon a tub or barrel, 136
Copper, 509
and iron, why sonorous, 75
sheathing of vessels, decay of, 287
the best conductor, 279
Copperas, 379
Copperplate printing, 438
Cordials, 399
Cork, why, floats upon the surface of water, 10
Cornea, 253
Cornice, definition of, 56
Cornish steam-engine, 158
Corpuscular theory, 230, 249
Cortical fibres, 419
Cotton, 421
best adapted for lamp-wicks, 23
known to the ancient Indians, 422
staple of, 421
unknown to Jews and Egyptians, 422
Coughing, explanation of, 84
Countries least cloudy, 200
most cloudy, 200
Country air, 327
Courtois discovered iodine, 361
Cowl, its use on chimneys, 173
Cream rises to surface of milk, 21
Cretaceous formation, 492
system, 492
Crop out, strata said to, 461
Crops, rotation of, 371
Crown glass, 364
Crust of the earth, 458
Crying, explanation of, 84
Crystalline bodies, 177
Crystallisation, 134
develops heat, 181
influence of light on, 184
how most easily effected, 184
of sugar, 178
substances capable of, 178
Crystallising substances expand, 131
Crystallography, 527
anorthic, or double oblique, 531
common form of, 527
cubical, 528
definition of, 527
faces, edges, angles, axes, 527
how described, 527
irregularly formed, 527
oblique, 531
produced by artificial means, 527
pyramidical, 529
rhombic, 530
rhombohedral, 530
secondary forms of, 527
twin crystals, 527
various systems, 528
Crystals, 178
defined, 178
elements of, 178
faces of, 179
figures vary, 179
forms of, 177
how formed, 181
how used for distinguishing minerals, 178
of the same substances similar, 177
two classes of, 178
Cumulus clouds, 205
how imitated, 205
Cumulo-stratus clouds, 207
Cupping, operation of, 62
Currents of air, 186
of air from the poles, 186
Curtain, why placed behind a speaker, 86
Cyanogen, 321
Cylinder boiler, its advantages, 159, 163

Daguerreotype developed, how, 264
discovered, when, 263
formed, how, 264
principle of, 264
taken in darkness, 265

Darkness defined, 234
Davy's, Sir H., attempt to protect the sheathing of vessels, 281
Davy's lamp, 346
Decanter stopper sometimes sticks, 137
Decay, 305
a species of combustion, 305
of wood, 305
Deceptions of vision, 255
Decimetre, definition of, 18
Density and porosity, connection between, 3
definition of, 3
of air in rainy weather, 211
Deserts, their effect on winds, 192
Deviation of needle, 292
Devonian system, 471
Dew, abundance of, in the morning, 115
abundant on cultivated land, 116
and rain compared, 115
cannot be said to fall, 118
defined, 114
deposited freely, when, 115
on woollen cloth, 116
does not cover the exposed parts of our bodies, 120
Dr. Wells's theory of, 121
evening, injurious to health, 117
ground covered with, 114
in Polynesia, 121
influence of winds on, 117
on colours, 118
under a leafy tree, 115
more abundant in autumn, 116
most abundant, when, 115
copious after a hot day, 116
in tropical climates, 120
none on a windy night, 116
not deposited readily on polished metal, 116
not formed on the surface of water, 120
on ships, 120
point explained, 119
produced at any time, how, 119
rare in large cities, 118
rarely deposited on rocks, 142
round, why, 119
Diamagnetic bodies, 297
Diamond, 322
brilliancy of, 243
properties of, 322
inflammable, 241
largest known, 324
weight of, 324
Diamonds, where found, 324
Diluvial systems, 488
Diluvian or drift, 471
Diluvium, 464
Dip of rocks, 461
Dipping needle, 293
how affected at the magnetic pole, 294
position of, at the equator, 297
Directive power of the magnet, 295
Distance, 257
Distillation and evaporation, 150
definition of, 149
simple, how affected, 150
Diurnal variation of the needle, 296
Diving bells, phenomena accompanying the descent in, 63
Divers, pearl, frequently deaf, 64
Dodo, 488
Dogs, why, shake their skins to free themselves from water, 27
Doors, double, use of, as a protection against cold, 105
Double vision, how produced, 255
Dovetailing, definition of, 50
Draining, 456
land, how promotes warmth, 456
Draught, inwards, through the crevices of windows, 171
Dresses, white, why worn in summer, 123
not worn in winter, 123
Drift, 471
Drops, the difference of bulk in different liquids, 7
prescription of medicine by means of, unsafe, 7
Drowned persons, why does the body float after some days, 20
Drum produces sound, why, 82
Dry air does not exist, 154
Ductility, definition of, 8
Dust, how we free our clothes of, by agitation, 28
less rises at night, why, 115
Duty of an engine, 159
Dwellings warmed by steam, 155
Dyeing and callico-printing, 431

Ear trumpet, construction of, 87
musical, definition of, 81
tympanum or drum of, 73
Earth absorbs solar heat, 93
Earth, a spheroid, 467
attracted by a feather, 11
density of, 457
effect of an increased rapidity of its revolution, 26
effect of the rotation of, on the air, 189
extent of surface, 458
form of, 457
once fluid, 466
radiates heat, 115
when colder than the air, 115
when warmer than the air, 115
Earthen and porcelain vessels burst, when, 134
Earthenware, 377
Earthquakes, 482
and volcanoes, probable cause of, 94
Ebb and flow of sea, effects of, 135
Ebullition and evaporation, difference between, 147
explanation of the phenomena of, 147

Echo, origin of, 85
situation of bodies for the production of, 85
not produced in an ordinary-sized room, 85
Echoes, remarkable, 85
Economical geology, 505
Effervescence, 329
Efflorescence, definition of, 180
Egg, difficult to break by pressing directly upon its ends, 52
floats in brine and not in water, cause of, 19
Eggs cannot be boiled on the top of very high mountains, 63
stale, why do they float, 21
Elasticity, 145
Electrical eel, 272
Electricity, 267
a source of heat, 94
accumulation of, 267
animal, 272
communication of, 269
conductors of, 269
connection with light and heat, 271
cools air, when, 270
current of, how generated, 267, 274
definition of, 267
developed, 267
Du Fay's theory, 269
electric and non-electric, fallacy of, 269
electric properties of amber, 267
employed for measuring time, 303
experiment with pith ball, 268
Franklin's theory, 270
how excited, mechanical power, chemical action, &c. 267
influence of the shape of a body in retaining, 269
invisible, 267
kinds of, 269
known to the ancients, 267
not the cause of all unexplained phenomena, 271
odour of, 268
ordinary mode by friction, 267
positive and negative, plus and minus, 270
produced by change of state in bodies, 270
torpedo, organs of, 271
velocity of transmission, 271
vitreous and resinous, 269
what is, 267
Electrical machines, 272
Nairne's, 273
Otto de Gucricke's, 272
Ramsden's, 272
Winkler's, 272
Electric telegraphs, 300
chemical (Bain's), 302
dial, 300
Electric telegraphs, invention of, 300
signal, 301
varieties of, 300
Wheatstone's discoveries in, 300
writing, 301
Electro-magnetism, 297
definition of, 297
phenomena connected with, 297
Professor Henry's experiment with, 298
Moll's experiments with, 298
Faraday's experiments with, 298
Electrometer, what is, 274
Electrotyping, 288
principles of, 288
process of, 288
Elements, four, of the ancients, 307
Endogenous plants, 419
Engine, atmospheric, 167
condensing, 168
expansive, 167
low-pressure, 167
non-condensing, 168
Engraving and lithography, 433
Entablature in architecture, 56
Equator, average temperature at, 93
Equinoctial storm, 228
Etching, 436
Evaporation, 150, 208
effects of, 150
how carried on and produced, 150
how productive of cold, 153
not confined to the surface of the earth, 153
spontaneous, 146
Evening star appears near, 257
how accommodates itself to darkness and light, 237
how caused to contract by intense light, 237
when struck, we see light, 253
parts of, 252
pupil of, what is, 252
why pained by sudden light, 271
Eyes of flies, 254
two, use of, 255
Eyelashes, use of, 254
Eyebrows, use of, 254
Eyelid, 254
Expansion, 128
of solids, liquids, and gases, 131
ratio of, 132
Expansive engine, 163
Explosive substances, 45
Exogenous plants, 419
Exogenous tree, age of, 420
Explosions of boilers explained, 163

Fagade of a building, 55
Falling bodies, rule for calculating the height, 31
Fanning cools the face, 124
increases the heat of the air, 124
Fan, use of, does not cool the air, 124

Faraday's electric theory, 297
his arrangement of conductors, 281
his observations on magnetism, 298
Fahrenheit's thermometer, 140
Fast colours, 432
Fat and oil, difference between, 409
people throw back their heads in walking, 13
Fats, 408
and oils float on water, 411
of vegetables, 410
used for greasing leather, 410
Fauna and flora of the oolitic period, 503
Feather, falling, attracts the earth, 11
Feet, why often feel cold near a good fire, 111
Feldspar, 375
Felting of wool, 425
Ferment, 395
Fermentation and putrefaction defined, 394
Fermentation, vinous, 396
Fibre of cotton magnified, 421
Fibres, capsular, 421
cortical, 419
foliaceous, 419
of flax and hemp, 422
Fibrine, 406
Fibrous substances, nature of, 421
Figure of a body, 2
Filtration dependent on porosity, 4
Fine silver, 305
Fire burns well in frosty weather, 334
covered, why, 334
damp, 345
effect of, to produce wind, 335
explanation of, 90
fly, light of, how produced, 258
intensity of, 334
places, 171
produced by friction, 97
Fires placed near the floor of a room, 111
Fishes enabled to ascend to the surface of water, 20
unable to live in water deprived of air, 67
Flame, 331
definition of, 90
hottest part of, 341
not equally luminous, 340
yellow, 340
Flannel keeps us warm, 353
preservation of ice, 104
Flax and hemp, fibres of, 422
have no staple, 422
preparation of, 422
Flea, relative strength of, 41
Flies, enabled to walk upon ceilings, &c., 64
Flint and steel, production of sparks by, 97
sparks in a vacuum, 97
glass, 364
Flowers, how propagated, 452
Flue boiler, construction of, 163
Flues, use of black-lead in blackening, 113
Fluids and solids, difference in the pressure of, 57
effect of heat on, 132
phenomena of, 57
pressure of, 57
surface of, at rest always level, 57
Fluorine never been found pure, 362
Flux, 366
Flying, difference of, from leaping, 29
Fly-wheel, advantage of, 164
Focus of light, what is, 245
Fog and mist, their difference, 209
cause of, 204, 208
does not become dew, why, 209
Fogs, 210
more general in autumn, 210
occur at night, when, 209
over the banks of Newfoundland, 211
over shoals and sandbanks, 211
round capes and headlands, 210
Food, 349
more required in cold weather, 354
Force and impetus of a body, on what depends, 9, 30
defined, 6
production and application of, 34
Forces, external and internal, 6
Forked lightning, 276
Form of aerolites, 224
of the earth, 457
Forms of aurora, 256
Fossil, 469
Fossiliferous rocks, 471
Fossils, how preserved, 470
of upper silurian rocks, 500
Franklin, electric theory of, 270
his discoveries, 279
Franklin's experiment, 279
kite, 279
Freestone, 5, 8
Fresh air, how much required in a room per hour, 326
Friction, definition of, 8, 97
heat produced by, 97
influence of, in exciting electricity, 267
matches, 98
Frieze, definition of, in architecture, 56
Frogs and fishes cold-blooded, 353
Frost and snow, crystals of, 181
Frostwork figures, always limited by certain angles, 180
on windows, origin of, 180
Frosty weather, less chilly than a thaw, 136
Frozen dew, 222
fog, 222
Fruit-trees, propagation of, 450
Fruits, hard when unripe, 389
juices of, yield syrup, why, 390
Fuel, 332
burns, why, 309
Fuller's earth, 374
Funnel of a chimney, definition of, 172

Gallery of a public building, why the hottest place, 171
Gallic acid, 379
Gallon, standard, how obtained, 17
Galvani, 282
his observations on electricity, 283
Galvanic action influences chemical change, 285
battery, 83
circuit, 284
current, how excited, 283
electricity, 282
trough pile, 285
voltaic pile, 285
Galvanism, 282
Gamut, definition of, 82
Garden, best situation for, 440
Gardening, 439
Garden walks, how laid out, 440
Garlic, odour of, 416
Gas, definition of, 5, 185
difference of, from a liquid, 5
light, 344
produced, how, 345
Gaseous bodies, varieties in nature, 58
Gases and liquids, difference between, 5, 58
expanded by heat, 128
Gasometers, construction and principle of, 65, 66, 364
Gelatine, 406
Gems, 183
small, more perfect than large, 183
Geological changes, 500
Geology, 457
changes, how effected, 459
changes in, existing and recent, 473
definition of, 457
derivation of the word, 457
economical, 505
metals, 506
mines, 511
first great fact of, 459
formation of, 471
of boiling springs, 480
of earthquakes, 481
of stratified rocks, 489
of submarine eruptions, 486
of the origin of caverns, 487
of volcanic craters, 475
rocks in, 460
scientific division of, 457
what it teaches respecting the origin of the earth, 465
German silver, 367
Giant's Causeway, 462
Glacier, definition of, 187, 220
Glaciers, increase of, 187
Glass, 364
and earthen vessels break, when, 136, 184
chimneys of lamps, 138, 332
crown, 364
flint, 364
Glass, plate, 364
reflector, 248
Glasses, burning, why ignite substances, 91
Glaze, 376
Globular lightning, 377
Glottis, definition of, 83
Glowworms and fireflies, why shine in the night only, 258
Glue, gum, and starch, why adhesive, 151
Gold, 384
large masses of pure, 384
leaf, 334
not affected by the atmosphere, 310
proof of the porosity of, 4
solvent for, 384
value of, 384
Gorges, how formed, 487
Gothic order of architecture, origin of, 54
peculiarities of, 54
two species of, 54
Governor of steam-engine, 165
Graduation of thermometers, 140
Grafting, 450
Grain weight, definition of, 16
how made, 16
Gramme weight, definition of, 18
Granite, 175
Grape-sugar, 389
Graphite, 322
Gravity, 10
centre of, 11
centre of, in irregular-shape-bodies, 13
Gravitation, definition of, 10
common property of all bodies, 10
Grass devoid of colour, when, 249
snow, 219
Grindstones in rapid motion, why liable to burst, 26
Ground colder on a clear than cloudy night, 115
covered with dew, 114
ice, 133
surface of, hardened by the sun, 186
Growth of plants, 494
Gum, 445
Gun, recoil of, when loaded with fine shot, 44
Gun-cotton, 45
essential properties of, 43
Gunpowder best adapted for explosive purposes, 45
compounds more explosive than, 321
described, 43
discovered, when, 46
explosive force of, 43
manufactured in little grains, 44
Gypsum, 372
called plaster of Paris, why, 372

Hail, what is, 219
cause of, 259
Hailstones, shape of, 220

Hailstorms, occur where, 220
Halls for music, construction of, 86
Haloes, explanation of, 246
Hand, held concave behind the ear assists the hearing, 87
Handkerchiefs, linen cooler than cotton, 105
Handles of metal, why warmer than wooden, 102
Hands and faces, why made warm by friction, 97
and lips chap, when, 226
Hardness of a body, on what depends, 8
Hard water, 312
how made more soft, 314
Hartshorn, 320
Hay, injured by heating, 337
odour of, 416
scales, how constructed, 37
Haystacks catch fire, 337
Haze round the sun indicates rain, 208
Haziness, cause of, 203
Headache produced by a crowded room, 326
Health, 355
pure air necessary for, 326
Hearing different in different persons, 60
human, boundaries of, 81
Hearthstone, cold to the feet, 102
Heat, absorbed most freely by what substances, 116
absorbers of, not good reflectors, 122
absorption and communication of, 123
and cold, sensations of, 89
and light, relations between, 90
best reflectors of, 123
black absorbs, 118
clouds prevent the radiation of, 121
communicated by contact, 100
radiation, 101
communication of, 100
conductors of, 101
definition of, 88
derived from electricity, 94
differs from other agents, how, 89
diffusion of, 89
distributed, how, 148
earth radiates, 114
effect of, on a magnet, 295
on dissolving power of liquids, 131
on fluids, 131
effects of, 94
enumeration of the best reflectors of, 123
evolved by chemical action, 330
expands air, 128
form of bodies dependent on, 128
greatest artificial, ever measured, 93
natural, 92
in ice, 89
internal, of the earth, 94
intense, how measured, 138
instruments for measuring, what called, 138
Heat, its tendency to liquefy solids, 131
latent, 95
phenomena of, 88
measured, how, 138
melts metals, why, 143
nature and sources of, 88, 90
not produced by friction of liquids, 98
of the sun different from all other heat, 90
passes from a body in right lines, 121
produced by chemical action, 94
compression, 99
easily by the friction of rough surfaces, 98
friction, 98
produced by mechanical action, 96
vital action, 97
applied to rooms, 171
rays of, 121
reflected, not visible, 123
reflection of, 122
reflectors, why made of polished metal, 122
solar, changed by radiation, 126
soot absorbs, 125
transmission of, 121, 127
weight of, imperceptible, 88
what bodies permit it to pass freely, 127
Heavy metals, 377
Hectometre, definition of, 18
Height of aurora, 226
of meteors, 223
of tides varies, 316
lightning clouds, 276
Henry, Prof., his electro-magnet, 298
Herbivorous animals, 493
Hiccough or hiccup, what is it, 84
High-pressure engine, 161
operates how, 161
parts dispensed with, 162
engines, when used, 161
safety of, compared with low pressure, 161
steam, 161
its mechanical power, 161
Hoarfrost, 125, 222
Holders, paper or woollen, why used, 102
Horizon, 257
Horn, transparency of, 246
Horse-power, definition of, 168
Horse-shoe magnet, 295
Hot air, houses heated by, 174
Humus, 387, 522
Hunger produced by work, 408
Hurricane, 194
Hurricanes travel from the equator, 195
breadth of, 196
surface of, 196
velocity of, 195
Hydraulics, definition of, 56
Hydrochloric acid, 361
Hydrofluoric acid, 362

Hydrogen and water, 312
discovered, when, 311
gas, characteristics of, 311, 345
Hydrometer, 21
Hydrostatics, science of, 56
Hygrometers, different kinds of, 213
Hyperoxide, 310

Ice, 133
anchor or ground, 133
crystals of, 219
filled with air-bubbles, 132
floats upon water, 19, 134
fracture of, angular, 181
heat in, 97
lighter than water, 132
melted by heat of the sun, why, 143
melting, temperature of, 96
of running water rough, 132
possesses antiseptic power, 133
preserved in flannel, 104
sea-water, fresh, 132
Icebergs, how formed, 187, 221
size of, 187, 221
Icicles, how formed, 133
Ichthyosaurus, 493
Identity of lightning and electricity, 276
Igneous rocks, 469
Illuminating power of light, 233
Image in a mirror, 235
in water, 236
Impenetrability, definition of, 2
Incandescence, 90, 258
Inch, standard, how determined, 16
Incidence, angle of, 236
line of, 236
Inclined plane, definition of, 38
familiar examples of, 38
Indian Ocean, trade-winds in, 192
summer, 192
India-rubber, 413
bed-coverings, why not used, 174
Induction, 290
Inertia, force necessary to overcome, 89
what is, 8
Inflammable bodies, refractive power of, 241
minerals, 523
Ink, blotting-paper absorbs, 23
for writing, preparation of, 380
blue, from what prepared, 380
stains of, extracted, how, 380
Iodine and fluorine, 361
Inorganic chemistry, 304
substances, 304
Insects, winged, how produce sounds, 85
light, why able to walk upon water, 7
Instrument, sounds flat when unstrung, 82
Instruments, stringed, purpose subserved by the body of, 76
Insulation of telegraphic wires, 302
Intensity of light measured, 233
Iridium, 368, 385
Iris, 252
Iron, 377
and granite, dissolved, how, 175
and steel, hardened, how, 184
made soft, 184
rendered magnetic, 293
becomes hot in a fire, 89
colder than wood, 102
cast, crystallisation of, 182
melting point, 93
cast and wrought, 182
effects of continued vibration on the structure of, 182
hot, bends more easily than cold iron, 143
by hammering, 97
hisses when immersed in cold water, 144
made cold by convection, 110
mass of, weight on the top of a high mountain, 15
rendered magnetic, 290
rusts, why, 309
sinks in water, 19
sulphuret of, form of crystals, 182
wrought and cast, 378
fibrous condition of, 182
ships, why do they not sink, 21
Islands, temperature more equable than continents, 124
warmer in winter than the main land, 124
Isomeric bodies, 416

Jacobi, Prof., his experiments, 299
Japanning, 412

Kakodyle, 417
Kaleidoscope, description of, 237
Kane, his observations in Arctic regions, 199
Kettle, bottom and sides should not be polished, 126
effect of heat at the top, 108
lid of, why hot when the wate boils 105
Kilometre, definition of, 18
Kyanising, 383

Lac, 413
Lacquering, 412
Lamb and veal contain albumen, 404
Lamps, ancient, 342
argand, 343
mechanical (Carcel's), 343
pump or spring, 343
Lamp-wicks, cotton best adapted for, 23
Land animals, first remains of, 490
breeze cool, why, 193
on tropical islands, 193
Lard and tallow, difference between, 410
manufactured by high-pressure steam, 193

Larynx, definition of, 83
Latent heat, 95, 144
theory of, by whom originated, 96
Laudanum, sixty drops equal to one hundred of water, 7
Laughing gas, vocal action of, 84
Lava, how different from other igneous rocks, 461
Lavender water, 415
Lavoisier first burnt the diamond, 347
Layers, 197
Lead, 381
and cotton, weights of, compared, 15
poisonous, 381
when exposed to the air becomes dull, 310
why called heavy, and feathers light, 4
Leap, standing, shorter than when running, 28
Leaping, difference between flying and, 29
use of running in, 28
Leather, black colour of, 380
how manufactured, 391
Leavened bread, 401
Leaves, green, 248
of trees affected by weather, 229
turn brown, why, 295
why attracted to the shore of a pond, 11
Leguminous plants, 394
Lens, definition of, 245
Lenses, varieties of, 245
Lever, arms of, 34
circumstances, which limit the utility of, 37
definition of, 34
Levers, effects of, in accumulating power, 36
of the first kind, examples of, 35
second kind, examples of, 35
third kind, examples of, 36
Life, first manifests itself in what form, 442
Light and actinism, 229
and heat, relations between, 90
absorption of, definition of, 232
absorbed, what becomes of it, 246
artificial, 258. 286
illuminating power of, 233
Light, cause of the refraction of, 240
chemical principle of, 261
position of, in the spectrum, 243
depth to which it penetrates the ocean, 247
excites magnetism, 296
focus of, 245
how polarised, 259
galvanic, 386
influence on crystallisation, 184
intensity of, measured, 233
moves in straight lines, 234
not always attended by heat, 258
no weight in, 230
Light polarised, what is, 260
phenomena of, 260
pencil of, 233
propagated, how, 233
radiating from a centre, effect of, 306
ray of, bent, 240
compound, 242
how divided, 242
rays of, how gathered by a telescope, 238
refined sort of matter, 230
reflected by a mirror, 236
by mirrors, 236
reflection of, 232, 237
refraction of, 240, 259
smooth surfaces reflect it best, 248
sources of, 230
velocity of, 230, 250
compared, 231
vibration of, 249
Lightning, causes of, 274
conductors, 279
follows the best conductors, 276
how divided, 276
mechanical effects of, 278
more common in summer, 275
passes down a man, how, 278
rod, how erected, 279
travels faster than thunder, 277
what is, 274
Lime, 442
carbonate of, 491
caustic, why made hot by the application of cold water, 95
effects of, as manure, 442
slaked, definition of, 50
why excluded from the air, 50
Limestone, 326
Line of incidence, 236
of reflection, 236
Linen, why cooler than cotton, 105
Linens, 424
Liniment, 409
Liquefaction, 143
Liquid and solid, difference between, 143
boiling-point of, what is, 147
definition of, 5
difference of, from a gas, 5
Liquids and gases, the difference between, 58
boiling points of, always constant under the same circumstances, 148
cooling of, how best effected, 110
expanded by heat, 131
heat not produced by the friction of, 98
height to which they can rise in tubes by suction, 68
impart no additional heat after they boil, 147
not good conductors of heat, 103, 108
power of, to conduct heat, 111

Liquids, power of, to conduct sound, 74
rise in tubes by suction, the reason of, 68
the "spheroidal" shape, 144
temperature of, when in the spheroidal state, 145
why well adapted for measuring changes of temperature, 139
Lithography, 438
Lithographic printing, 439
Loadstone, 289
Loaf-sugar, how refined, 372
Loam, 439
Locomotives, 168
Locusts, how produce sounds, 85
Longitude, meridians of, 17
Low-pressure engines, 161
water, 316
Lower silurian formation, where situated, 500
Luminous bodies, 258
Lunar caustic, 320
Lungs, 349

Machinery, concussions and vibrations in, to be avoided, 182
Machine defined, 33
object of, 40
Machines add to human power, 33
and manufactures, sources of advantage of, 33
do not create power, 33
make objects apparently worthless valuable, 33
produce economy of time, 33
Magellan, Straits of, elevation at which water remains frozen, 187
Magnet, a natural, 289
directive power of, 291
horse-shoe, 295
retains its magnetic property when broken, 293
Magnetic effects of lightning, 278
meridian, 291
needle, 291
reversed, 291
phenomena, 289
polarity, 290
poles, greatest cold felt there, 296
of the earth, 291
variable, 292
power resides, where, 293
Magnets, proper position for, 295
Magnitude and impenetrability, 2
defined, 2
Malignant disease, 408
Malt, how converted into beer, 398
Mammoth, 490
Man, alone fitted for all climates, 700
ordinary strength of, 41
races of, 541
American, 543
Caucasian, 542
Man, races of, Ethiopian, 544
Malayan, 543
Mongolian, 543
distinctions of, 542
identity disputed, 541
Schlegel, quotation from, 541
varieties of, 541
respires, how, 349
Manganese, 365
Manufactures defined, 418
object of, 418
philosophy of, 418
Manure of different animals, 441
Manures, 441
calcareous, 440
common animal and vegetable, 441
kinds of, 441
mineral, 441
Marble, 272
Mariner's compass, 291
Marl, 522
Marsh gas, 345
Mastic or mastich, definition of, 51
Mastodon, 490
Matches, why not ignite when damp, 151
Materials, application of, for architectural purposes, 48
Matter defined, 1
evidence of its existence, 1
limits to the division of, 2
molecule of, 3
particle of, 3
Mauritius, region of hurricanes, 194
Meat covers should be plain, and not chased, 113
rendered tough, how, 405
subject to taint on moonlight nights, 117
Mechanic powers, three great divisions of, 34
science of, 33
Mechanical action, a source of heat, 96
force, 158
powers, how do they assist labour, 5
Medicine, the prescription of, by drops, unsafe, 7
Meerschaum, 373
Men, fat, swim easier than spare men, 20
Mercaptan, 417
Mercury, 383
boils at a high temperature, 93, 142
contracts in freezing, 132
freezes at what temperature, 93, 141
iodide of, change in the crystals of, 184
used for thermometers, 139
Meridians, definition of, 17
Metal, hot, why seem warmer than hot wool, 102
fused by lightning, 279
Metallic bodies, 306
elements, 383
Metalloids, 307

Metallurgy, 384, 506
Metals best adapted for showing thermo-electricity, 289
cannot be changed, 307
colour of, 507
copper, 509
electro-chemical action on, 506
gold, 507
iron, 507
lead, 509
melted by heat, why, 143
of alkaline earths, 371
ores, 506
platinum, 507
silver, 507
steel, 507
temperatures at which they burn, 127
their number, 307
tin, 509
zinc, 509
Meteoric iron, 224
showers, 225
Meteorites, 223
their origin, 223
Meteorology, definition of, 185
imperfectly understood, 228
Metre, definition of, 18
Mezzotint, 437
Miasma, 408
Mica, 524
Microscopic plants in snow, 219
Milk, boils more readily than water, 111
quicker than water, reason of, 111
curdles when sour, 401
turns sour by keeping, 401
Millimetre, definition of, 18
Mineral, fracture of, its utility, 525
its lustre depends on what, 526
manures, 441
species, constituents of, 523
their number, 523
springs, 312
vein, 506
Minerals, their fusibility, 526
scale of hardness, 525
which possess taste, 526
Mineralogy, 523
Mining, blasting with powder, 517
introduction of steam power, 517
mechanical preparation of the ore, 515
motive power commonly employed, 514
neglected in E gland, 517
operations known at an early period, 516
ordinary process, 515, 516
produce of, brought to the surface, 513
recent improvements, 518
safety apparatus, 514
shafts, 513
ventilation, 513
Mines, 510
blasting of, 511
boring for, 511
Mines, drainage of, 511
purpose of working them, 510
supports of, 512
tools employed, 511
Mirage, 242
Mirror, 235
concave, 235
convex, 235
light reflected by, 236
plane, 235
Mirrors, how made, 365
reflect light, 236
Mist and dew, 208
and fog, 208
their difference, 209
vanish, when, 118
cause of, 118, 208
and dew, 118
phenomena of, 118
sometimes white, 210
Modifications of clouds, 204
Moisture on the hand, 145
Molasses, 390
candy, why sticky and gum-like, 178
oil, &c., occupy less space in summer than in winter, reason of, 138
Molecule of matter, definition of, 3
Momentum of a moving body, definition of, 30
Monsoons, 192
change of, how marked, 193
their limits, 192
useful to the mariner, 193
Moon appears larger than the stars, 237
as seen through a telescope, 468
farther off when in the horizon, 257
how makes a path of light in water, 236
light of, compared with sun, 231
Moonlight nights, 117
no effect on putrefaction, 228
Mordants, 432
Morning, gray, indicates a fine day, 203
Mortar, 328
becomes hard, 50
proportions of lime and sand in, 50
use of hair in, 51
why used, 7
Mortars and howitzers, 46
Mortising, definition of, 49
Moscow, burning of, 198
Motion, accelerated in falling bodies, 30
apparent, of distant objects to a person riding or sailing, 25
axis of, in a revolving body, 30
centre of, in a revolving body, 30
communication of, never instantaneous, 26
definition of, 24
diffused effects of, 32
effects when suddenly impeded, 9
how communicated to steam-engine, 159

Motion of the earth, 24
perpetual, 9, 40
rotary and reciprocating, definition of, 34
state of things if none existed, 24
Mouldiness in ink obviated, 380
Moulding, 375
Mountains, distant, why appear blue, 60
high, always covered with snow, 186
noiseless and quiet, 74
Mountainous countries rainy, 215
Muriatic acid, 360
Muscular energy, how exerted, 41
Musical chord, number of vibrations necessary to produce sound, 81
glasses, why produce sounds, 82
instrument, four classes of, 82
sounds, definition of, 80
and mere noises, difference between, 80
Musk, 414
Muslin, how protects plants from frost, 117
Mustard, its composition, 413
Mutton, solid, why, 409

Nails in old houses, why loose, 137
Naphtha, 413
Nature and production of electricity, 267
of fibrous substances, 413
Navigation, steam, originated where, 169
Neap tides, 316
Neat's-foot oil, 410
Nebulæ, 466
Needle, dipping, 293
floats upon water, 7
magnetic, 291
of compass, points how, 292
Negative electricity, 270
Negro's skin never blisters, 125
Network of ice, how formed, 134
Neutral body, 306
Newcomen, his experiments, 165
Newton, his prediction of the diamond, 241
Nimbus clouds, 207
Nineveh, glass found there, 366
Nitrate of strontia, 373
Nitre, 319
Nitric acid, 319
Nitrogen and its compounds, 317
chloride of, 45
defined, 317
not magnetic, 297
Non-condensing engine, 161
Non-metallic bodies, 306
North wind generally cold, 193
Nutcrackers, what kind of levers, 35
Nutrition and animal heat, 352
Nutritive value of meats, 405, 406
various fishes, 407

Oar appears bent, why, 240
Objects inverted, 255
Ocean affects climate, 188
Ocean, depth to which light penetrates, 247
green, or blue colour, 60
how much of the earth covered by, 458
Ochre, 378
Odoriferous principle of plants, 415
Odours, animal, 414
artificial, offensive, 417
compared to notes in music, 417
origin of, unpleasant, 416
Oersted, his discoveries, 297
Offsets, 452
Oil, 408
and water will not unite, why, 305
cloth, 412
neat's-foot, 410
of cinnamon, 416
on water, prevents freezing, reason of, 106
silk, 412
thick in winter, 410
water will not dissolve, 175
whale, 410
Oils, drying, 412
volatile, 415
Oldest strata, 501
Old red sandstone, 499
Oleine predominates in oils, 412
Olmsted's theory of shooting-stars, 225
Onion, odour of, 416
Oolite system, 492
Oolitic period, fauna and flora of, 503
Opaque bodies, what are, 246
Opinions concerning the weather, 227
Optical delusion, 257
Optics, 229
Orders of architecture, 52
Ore, metals generally found in, 367
Ores, occur how, 506
Organic chemistry, 386
substances, 304
Organs of vision, 352
Origin of colour, 247
of meteorites, 224
Osmium, 385
Oxide of iron, 378
of lead, 363
Oxides, 309
Oxygen, 308
and oxide, their difference, 308
its use, 308
magnetic, 297
Oysters, shells of, of what composed, 372

Paint, blisters through heat, 151
preserves wood, 106
Painters' colic, 381
Painting iron prevents its rusting, 309
Palæontology, 470
Palladium, 385
Paper, curls when scraped, 184

Paper for writing and printing, 430
ignition of brown, 124
making, 43
puckers when wet, 212
Papier maché, 431
Parallels of latitude, definition of, 17
Parian, 377
Particle of matter, definition of, 37
Peachstones, kernels of, poisonous, 321
Pearl ash, 370
"mother of," cause of colours in, 244
Peat, 333
Pedestal, definition of, 55
Pencil of light, 233
Pendulum, compensating, 138
definition of, 31
length of, effect on the rate of the clock, 32
marks time, how, 31
seconds, length of, 32
use of, 16
Perceptibility in sound, limit of, 87
Perfumery, preparation of, 417
Perfumes and odours, 414
use of, 403
Periodical winds, 192
Peroxide, 309
Perpetual motion, 8, 9
Perspective, meaning of, 237
Perspiration, cause of, 353
insensible, 208
Petrifaction, 314
Pewter, 368
Phenomenon of dew, 114
Philosophy of manufactures, 418
Phosphate of lime, 356
Phosphorescence, 258
Phosphoric acid, 357
Phosphorus, 356
and sulphur, 356
derivation of, 356
Phosphuretted hydrogen, 357
Photographic pictures, principle of formation, 262
Photography described, 261
Photometer, 233
Physics, definition of the science of, 6
Pianos, effect of temperature on, 137
produce musical sounds, why, 82
Pictet's theory of radiation of heat, 114
Pictures, not seen well in certain positions, 238, 344
Pilasters, definition of, 54
Pile, definition of, 43
Pin-cushion, how made as effective as a cannon ball, 25
Pipe, comparative strength of lead and tin, 381
Pisa, Leaning Tower of, 12
Piston, steam, 159
Plank, why more liable to break than a beam, 48
Plants acquire the carbon of their structures, how, 265
endogenous, 419
exogenous, 419
fold their leaves before rain, 212
growth of, 443
in snow, 219
nourishment of young, 444
respire, 350
rules for watering, 448
Plaster of Paris, 373
non-conducting properties of, 373
Plastic, definition of, 6
Plate glass, 365
Platina, specific weight, 19
Platinum, 310
and gold never oxidise, 310
solvent for, 385
Plesiosaurus, 493
Pliant, when is a body, 8
Plinth, in architecture, 55
Plumb line, 14
rule, 14
Plummet, 14
Plumule of the seed, 444
Plutonic rocks, 460
Pneumatics, science of, 58
Point-blank, definition of, 46
Poker, why feels colder than the hearth-rug, 102
Polarisation of light, 259
Poles of the earth, 291
Polypes respire, how, 401
Pomatum, 415
Pop-gun, why occasions a loud report, 84
Porcelain, 375
clay, 525
Pores, existence of, in gold and lead, 4
of a body, definition of, 3
Porosity and density, 3
Porous bodies, conduct heat slowly, 112
Portico, definition of, 54
Positive electricity, 270
Potash, crude, of commerce, 369
whence principally derived, 369
Potassium, 367
Potato abounds in starch, 388
Potatoes at the top of a boiler, 111
sweet, why, 389
Power of magnets, 291
sources of, 40
Precious stones, 185
Primary colours, 243
Primitive rocks, 467
Printing, common process of, 433
copperplate, 438
definition of, 433
ink, its composition, 439
invention of, 433
lithographic, 438
machine, history of, 434
paper, 430

Printing press, 434
stereotype, 434
Prism divides a ray, 242
Prevost, theory of, 114
Projectiles, 45
Proof spirit, 399
Propagation of fruit-trees, 449
Protoxide, 309
Pudding-stone, 463
Pulley, definition of, 38
Pump, construction of common, 68
forcing, 69
handles cold in winter, 102
height of water raised by, 68
invention of, 69
Puna winds, 194
Pupil, 352
Pure water poison to fish, 313
Putrefaction, 228
Pyramid, difficult to overturn, 13
Pyrometer, how constructed, 142
the Gravezande, 142
used to ascertain the heat of furnaces, 143

Quadruped never raises both feet on a side simultaneously, 12
Quadrupeds learn to walk sooner than children, 15
swim easier than man, 20
Quartz, 362
Quicklime, application of, to fallow ground, 441
as manure, 442
called caustic lime, 373
described, 50, 328
Quills of birds, why hollow and cylindrical, 47
Quinine, 391

Radiation and reflection of heat, 123, 185
ceases in cloudy weather, 115
influence of colour on, 114
of heat, 112
on what depends, 112
two theories of, 114
Radiators, good absorbers of heat, 112
of heat, what substances are bad, 113
Radicle of the seed, 443
Railway carriage, first, 169
trains, why produce more noise in crossing a bridge than upon the ground, 79
Rain, amount of annual precipitation, 215
cooler after, 153
cools the air, 151
drop a sphere in form, 120
falls continually in some countries, 217
in drops, why, 211
more abundantly at the equator, 216
gauge, 215
more falls at night, 212
Rain, more falls in winter, 215
on the sea coast, 216
never falls in some countries, 216
none when the air is very dry, 72
purifies air, 212
quantity which falls at Vera Cruz, 215
snow, hail, frost, 211
some countries destitute of, 216
water not salt, why, 314
soft, 313
what is, 211
without clouds, explanation of, 115, 217
Rainbow, 243
how produced, 244
Rainy days, more in temperate zone, 213
Ratio of expansion of solids, 131
Rays, calorific, 121
of light diverge, why, 242
Ray of light, 240, 271
compound, 242
divided, how, 242
Razors dipped in hot water before using, 136
Reaumur's thermometer, 140
Redfield, his estimate of a hurricane, 197
his theory of hurricanes, 197
Red rays heating, 250
Reflection, angle of, 236
line of, 236
of heat, 122
of light, 236, 248
Reflectors, necessity for keeping clean, 122
the best, 123
Refraction of light, 240
double, what is, 259
explained, 241
illustrated, 241
phenomena of, 245
Refracting power depends on what, 241
Reid, his theory of hurricanes, 197
Reign of fishes, 502
of reptiles, 503
Repulsion, definition of, 6
Resin, 270, 411
Resins, fragrant, 414
Resonance, 85
Respiration, 347
a form of combustion, 348
Retina, 252
images formed on inverted, 255
retains impressions, 254
Retort, what is, 149
Retting or rotting of flax, 422
Reverberating furnace, 338
Richardson, his observations in Arctic regions, 199
Ricochet firing, definition of, 46
Rifles, bore in some, twisted, 44
Rifle, "Minie," peculiarities of, 43
more accurate in shooting than a musket, 43
Rivers and streams, effects of, 473

Rivers generally of a serpentine course, 27
velocity of, 58
Roads, constructed over the summit of a hill, bad policy of, 39
dried in a few hours, 152
effect of elevation of, in increasing labour, 39
Rocket ascends when fired, 21
Rock salt, 361
Rocks, 459
and stones, increase how, 474
classification of, 488
distinguished, 471
once in a state of fusion, 362
split in winter, why, 132
vertical order of position, 489
watertight, 519
weatherbeaten, 132
Roemer discovered velocity of light, 231
Roofs, steep, why best adapted to cold climates, 49
Room, air in, without a fire, why warmer than out of doors, 170
two fires in, apt to smoke, 173
Rope-walking, art of, 14
Rose diamonds, 324
red, its effect on complexions, 251
water, 415
Rotation of crops, 448
Rotatory movement of wind, effect of, 195
Ruins and mountains, why famous for echoes, 85
Rum, 399
method of stealing in the West Indies, 21
Rust, 309

Safety lamp, 346
valve, 163
Sal-ammoniac, 321
Salt, amount of, in sea water, 176
and snow colder than snow, 196
crackles when thrown in the fire, 181
crystallises, 180
dissolves ice, 136
formed from sea water, 176
in chemistry, 306
in springs, 314
in the ocean, 314
lakes, 314
water freezes, when, 135
Saltpetre, 319
of itself, will not explode when burnt, 321
quantity of, retained in boiling-water, 176
Sand of deserts, of what composed, 363
pillars, 199
variety most suitable for mortar, 50
Sandstone, 463
Sandy plains dazzle from sunshine, 249
Sap of a healthy tree, temperature of, in winter, 109
Sapphire, 526
Saturation, 175
Saucepan, blackened with soot, boils quicker than a bright one, reason of, 126
Savages, method adopted by, for distinguishing the approach of an enemy, 75
Savery, his experiments, 165
Scale in music, 82
Scarfing and interlocking, definition of, 49
Scion, 450
Scissors, pincers, levers of what order, 35
Screw, definition of, 39
perpetual, 39
Sea breeze, cause of, 193
cool, why, 193
on tropical islands, 193
evaporation of, greater than the land, 153, 189
salt, 314
salt in, 176
sickness, cause of, 29
water, freezing point of, 135
rarely frozen, 135
solid matter in, 315
substances contained in, 315
Sealing wax, 413
Seed, freshness of, 447
how made to grow, 443
leaves, 445
mode of testing, 447
of a plant, 443
one hundred years old, 447
Seeds germinate, how, 444
self-sown, 447
Seeing described, 252
double, why not, with two eyes, 255
Sensation, different impressions transmitted by each organ of, 1
effect of deprivation of, 1
Senses, number of, 1
what are they, 1
Serpentine, 524
Serpents live long without food, 350
Shadow, defined, 234
Shaft of a column, 56
Shavings obstruct the transmission of sound, 79
Ship in a hurricane, 197
Ships, impracticable to construct, beyond a certain size, 48
Shell-lac, 413
Shells, brightest near shore, 250
Sheet-lightning, 276
tin, 381
Sheets of a bed, why feel cold, 107
of linen, why cooler than cotton, 105
Shooting-stars, 224
Shot and cannon-balls, why heated by their discharge, 99
manufacture of, 382
Shuttle, 429
Silicious and earthy minerals, 523

Silicium and boron, 362
Silk, 425
a bad conductor of heat, 107
composition of, 426
oil, warm, 174
Silver, 383
difficult to keep bright, 310
nitrate of, turns black, 265
plating, 384
spoons, more heated in tea than pewter ones, 106
value of, 384
Simoom, 194
Simple and compound substances, 304
substances, number of, 304
Sizing of paper, its utility, 430
Skating swiftly over thin ice, effect of, 29
Slag, 366
Slate, why rebounds upon water, 56
Sleep, 355
Smell, organs of, 416
Smoke, 331
ascends a chimney, 10, 130, 173
definition of, 172
little with a red-hot fire, 334
rises up the chimney, why, 172
wreaths of, origin of, 172
Snapping of wood, coal, &c., 4
Sneezing, definition of, 84
Snow, a bad conductor, 218
a non-conductor of heat, 105
at the foot of a tree or wall, melts readily, 113
beneficial to the earth, 218
crystals of, 131
evaporation of, 153
flake, 219
green, 219
keeps the earth warm, 218
on the tops of high mountains, 123
perpetual line of, 186
protects vegetables from cold, 105
red, 219
white, why, 219
what is, 218
Soap, 409
Castile, 409
how manufactured, 409
properties of, 409
Soapstone, 524
Soda, obtained where, 369
Sodium, 369
Soils, bad conductors of heat, 105
best for a garden, 439
cooler in summer below the surface than the surface, 105
natural, 522
warmer in winter below the surface than the surface, 440
Solids converted into liquids, how, 131
expansion of, 131
power of, to conduct sound, 75
Solution and crystallisation, 175
Solution and mixture, their difference, 175
effects of heat on, 175
of salt, 175
Sonorous bodies, definition of, 75
vibrations, nature of, illustrated, 74
Soot, absorbs heat, 125
influence of, on cooking utensils, 125
prevents the escape of smoke, 175
Sound, air not necessary for its production, 74
attends the appearance of aurora, 226
communicated through a tube, 87
effect of irregular surfaces on, 86
interruption of, in damp weather, 79
loudness of, on what depends, 74
more distinct by night, 79
in cold weather, 79
perceptible near a water-spout, 198
produced by organs of voice, 83
reflection of, 86
sharp, generally loud, 80
transmission of, 75
velocity of, 77
Soup, why retains heat longer than water, 110
South magnetic pole, position, 291
winds generally warm, 193
Spar, Iceland, 259
Sparks fly from burning wood, 129
how produced, 129
of fire, origin of, 4
Speaking tubes, why used, 78
Specific gravity, definition of, 19
determination of, 19
difference of, from ordinary weight, 19
Spectrum, 262
Speculum, 235
Spermaceti, 410
Spheroidal state of liquids, explanation of, 144
Spinning, 426
mule, 428
Spirit above and below proof, 399
Spirits, boil quicker than water, 111
Sponge, 176
absorbs water, 6, 23
wet, cleans a slate, 176
Spontaneous combustion, 337
Spoons, metal, retard the process of boiling, 106
Spray of waterfalls causes rainbow, 244
Spring tides, 316
water contains earthy matter, 312
always cool in summer, 95
Springs, indicate change of weather, 229
origin of, 518
warm, when, 480
Squinting causes to see double, 233, 255
Stairs, common, varieties of inclined planes, 39
Staple of cotton, 421

Standard for comparing steam-engines, 168
Starch, 388
boiled before using it, why, 388
imparts a glazed surface to cloth, 152
manufactured, how, 388
stiffens linen, 152
Star-light, nature of, determined by polarised light, 261
Stars, number of, 257
twinkle, 245
Steam adapted for warming dwellings, 155
advantages of heating by, 174
appearance of, condensed, 154
at what temperature produced, 154
available in machinery, 157
burns more than boiling water, 95
compared with common air, 154
condensed into water, 156
contains more heat than boiling water, 155
cooking by, 156
defined, 153
engine, 157
condensing, 159
consists of two parts, 162
governor of, 165
greatest work of, 158
illustration of, 158
high-pressure, 157
in boiling-water first manifested, 154
invisible, 153, 154
its most important property, 155
its pressure how diminished, 156
how exerted, 155
lighter than water, 155
mechanical force of, 157
power of, 43
weight of, compared with air, 59
compared with water, 155
Stearine, 412
Steel, 325
engraving, 438
of a purple colour rusts easily, 310
Stems of grain-plants, why hollow tubes, 47
Stère, or the French unit of dry measure, 18
Stereoscope, 256
Stethoscope, construction of, 76
Stiffness of a material, 47
Stigmaria, 497
Still, definition of, 149
Stippling, 436
Stock, 450
Stone, durability of, how ascertained, 518
used for lithographing, 438
Stones, effect of loose, on soil, 522
gravel, and sand, why easily moved by waves, 22
snap when heated, 130
Stones, the precious, 524
Stove, rooms warmed by, how, 103
Stoves, advantages of, 338
ancient water, 174
hot air, 174
Stoves, known to the Romans, 174
manner of warming rooms by, 111
snap, when the fire is extinguished, 137
a fire is kindled in them, 137
St. Petersburg, quantity of rain at, 216
Strabismus, or squinting, 233
Strata at the bottom of the Gulf of Mexico, 473
crop out, when, 461
Stratified, 459
rocks, 469
Stratus, 204
clouds, how produced, 205
Straw, why used in ice-houses, 105
Strength, greatest active, of a man, 41
of materials, effect of shape upon, 47
Streets, watering, how cools them, 151
Strontium, 371
Strychnine, 391
Stucco, what is it, 51
Sublimation defined, 150
Suboxide, 309
Subsoil, important to have a good, 439
best kind of, 439
Substances, differently soluble, how separated, 304
simple and compound, 304
Substantive colour, 431
Sucker, common, operation of, 63
weight raised by, 64
Suffocation, explanation of, 84
Sugar, a vegetable and animal substance, 389
candy, 178
Sugar, composition of, 389
loaf, 178
melts in water and tea, 175, 176
method of refining, 150
of lead, 382
varieties of, 389
Sulphur, 357
Sulphuretted hydrogen, 358
Sulphurous acid, 359
Summer warmer than winter, 92
Sun, a source of heat, 90
does not actually rise and set, 25
heat of, and artificial, compared, 90
greater in some parts of the earth, 91
greatest at noon, 92
physical condition of, 91
power of, 92
production of heat and light, 91
rays of, when fall perpendicularly, 92
temperature of, 91
nature of, how determined by polarised light, 261
red through a fog, 204
Sunrise, cause of a red, 203
Sunset, cause of yellow, 203
gray, indicates wet weather, 203
Sunshine, effects on combustion, 91
Surf, 317

Surfaces, brilliant, 248
extent of, affects evaporation, 152
Sweet-wort, 398
Swimmers, unskilful, why liable to sink, 20
Swimming, why easier in salt than in fresh water, 20
Synthesis, 305

Tallow, what animals furnish, 410
Tannic acid, 379
Tap-rooted plants, 448
Tartar emetic, 385
Tartaric acid, 370
Tea and coffee, properties of, 392
cools quicker for stirring, reason why, 134
old people generally fond of, 392
pot, dull-black, does not make good tea, 113
effect of air-tight lids, 65
lids, hole in the top, use of, 65
Telescope, reflecting, definition of, 239
Telescopes, how enable us to see objects otherwise invisible, 239
varieties of, 239
use of, 238
Temperature, change of, 138
circumstances which influence, 187
defined, 138
disturbing causes of, 187
cultivation, 188
distance from the sea, 188
elevation of land, 188
geographical position, 187
mountain chains, 188
rain, 188
soil, 188
the slope, 188
winds, 188
effect of, on the distribution of animals and plants, 100
influence of the configuration of land on, 188
mountains, on, 188
sea, on, 188
soil, on, 188
mean, daily and annual, definition of, 186
mean daily, of a particular locality, how ascertained, 186
not the same at all places under the same latitude, 187
of the body, 353
of wind, effect of change of, 188
proper for a room in cold weather, 174, 208
reduction of, how affects the moisture of the air, 152
varies with altitude, 186
with latitude, 186
Tempering of steel, 378
Terra-cotta, what is it, 51
Tertiary formation, 471
period, animals of, 472
Textile fabrics, manufacture of, 418
Theine, 392
Theo-bromine, 393
Thermo-electricity, 288
Thermometer and pyrometer, difference between, 138
by whom invented, 140
centigrade, 141
construction of, 139
Fahrenheit's, 140
Reaumur's, 140
Thermometers, 138
comparison of, different, 140
graduation of, 139
mercury used for, 139
Thirst created by eating salt food, why, 405
Thunder clouds, 281
and lightning accompany hurricanes, 197
cause of, 281
its distance calculated, 281
purifies the air, 278
rolling of, 281
sound of, 281
storm, what is, 276
where most frequent, 276
Tide wave, velocity of, 316
Tides, 315
Tiles, what are, 51
Tin, 380
box, why used for foot-warmer, 113
foot-warmers, why covered with flannel, 113
Tinder, 322
Tissue, vegetable, 387
Toes, advantage of turning out, in walking, 13
Tone or pitch in sound, definition of, 80
when grave or sharp, 80
Tongs, pair of, levers of the third kind, 35
Tongue, hot-iron applied to, momentarily, does not burn, 145
Tongueing and rabbeting, definition of, 49
Top spinning, 27
Tower, circumstances under which it will stand securely, 12
Tornado, curious effect of, 197
Tornadoes, 197
their origin, 198
Torpedo, 271
Trade-winds, 190
blow all the year round, 191
do not blow direct north and south, 191
effects near the equator, 191
how produced, 191
in the Atlantic, 191
in the Indian Ocean, 192
motions of the Polar currents, 191
occasioned by, 191

Trade winds, region of calms, 192
uniform force, 192
upper and lower currents, 191
Train oil, 410
Transfer printing, 439
Transmission of heat, 127
Transparent bodies, 246
semi, 246
Transparency and opacity, 246
not perfect in any substance, 246
Trap rock, 462
Traverse, when a magnet is said to, 291
Tree, shady, why cool in the summer, 105
Trees, arrangements of the limbs of, in reference to the centre of gravity, 15
crack with frost, 132
vital action of, 107
why unable to grow unlimitedly, 48
Triasic, 471
Tropical islands, land breeze on, 193
sea breeze on, 193
Tropics, rainy season of, when commence, 216
Tropical wet day, 216
Turpentine, 411
oil of, 415
Turtle, why unable to move when placed on its back, 12
Tuscan order of architecture, 53
Twilight, cause of, 244
Twilled goods, how woven, 429
Twisted cord, strength of, 426
Type-metal, 386
Typhoon, 197

Unbolted flour nutritious, 401
Undulatory theory, 230, 249
Unstratified rocks, 460
Upper silurian, 471

Vacuum, definition and illustrations of, 170
in nature, 62
operation of, 62
perfect, cannot be made artificially, 62
Vapours, how condensed into liquids, 128
occupy more space than the substances from which they are produced, 145
Vaporisation, 144, 145
explanation of, 144
Variable winds, 192
prevail, where, 193
Variations of the magnetic needle, 292
Varnishes, 412
Vegetable life dependent on animal, 350
mould, 387
organisation, 387
tissue, 387
zones, the arctic, 534
the cold temperate, 533
the equatorial, 532
the polar, 533
the sub-arctic, 533
Vegetable zones, the sub-tropical, 533
the tropical, 532
the warm temperate, 533
Vegetables, decaying, 394
Vegetation, in tropical climates, 351
in arctic regions, peculiarities of, 534
influence of solar light upon, 265
effects of atmospheric pressure on, 533
of electricity on, 534
of moisture on, 533
of position of country on, 534
of soil on, 533
of temperature on, 533
temperate, 534
tropical, 534
Vein, mineral, 473
Velocity being known, to determine the distance passed over, 26
of a body moving uniformly, how determined, 26
of a falling body increases with the distance passed through, 31
of light, 231
of shooting stars, 225
of wind, 190
in a hurricane, 190
in a storm, 190
unsafe, instance of, how determined, 28
Ventilation of a room, how best effected, 171
what is, 169
Veratryne, 391
Verdigris, 382
Vermilion, 383
Vertebrated animals have lungs, 348
Vertical rays, 189
Vibrations, aërial, how communicated, 76
danger of, 182
necessary to produce yellow light, 249
to produce red light, 249
of sound, number capable of appreciation by the human ear, 81
sonorous, how made visible, 76
Vinegar, 391
sour, why, 391
Vinous fermentation, 396
Vision, deceptions of, 256
organs of, 252
Vital action, a source of heat, 99, 272
Vital force, 386
forces cease to exist, when, 304
Vitrifaction, 364
Voice, tones of, how made grave and acute, 83
Volatile bodies dissipated by heat, 153
definition of, 145
ethers, 415
oils, 415
Volcanoes, 475
form of, 475
number of, active, 479
probable cause of, 94

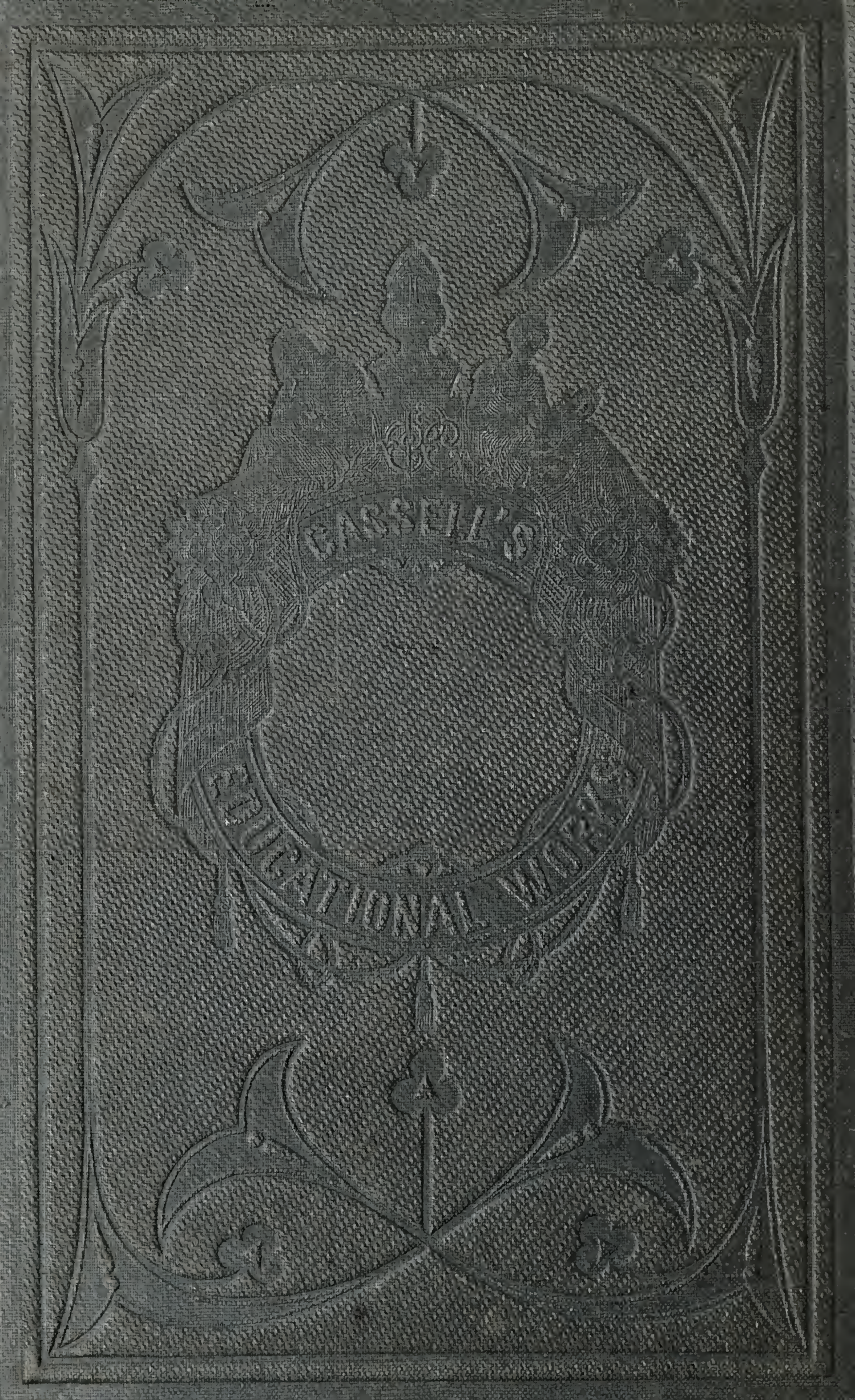
Volta, 285
Voltaic battery, 285
Volume of a body, 2
Vulcanised India-rubber, 413

Walking arm and arm, philosophy of, 13
Walls, construction of, for obstructing sound, 79
Warmth, definition of, 103
produces breeze, 193
Warming and ventilating, 171
Warp, wood, 151
Watch and clock, difference of, 32
Water, 312
a bad conductor of heat, 103
air in, 67
amount daily raised by evaporation, 217
an elastic body, 56
ascent of, in tubes by suction, discovery of the reason of, 69
boiled, why flat and insipid, 67
boiling, ordinary temperature of, 148
temperature increased by pressure, 148
boiling-point, 93
of, in a vacuum, 148
boils quicker in a metallic vessel than in one of glass, 148
can never be heated above the boiling-point, 147
cements, why become harder under water, 50
congelation of, effects of, 218
contracts, 134
converted into steam under what pressure, 58, 158
currents produced in boiling water, 109
declivity sufficient to give running motion to, 57
discharge of, from vessels, 58
dissolves sugar, why, 175
drop of, why rolls upon very hot metal, 45
expanded by heat, 34
expands in freezing, 3, 34
into steam, 144
expansion of, when freezing, 132, 151
extinguishes a fire, 333
falling, influence of gravity upon, in waterfalls, 31
freezing-point of, 93, 133
gas contained in, 334
how converted into steam, 154
frozen by rapid evaporation, 136, 150
made hot, 108
ice lighter than, 132
in freezing always crystallises, 218
may be heated beyond two hundred and twelve degrees F., 109
obtained by distillation purer than any other, 150
Water pipes, why they burst in frosty weather, 134
plants, 351
power, definition of, 41
purified, how, 4
purifies itself, when, 315
rise of, in small tubes, 23
rotted flax, 422
running, effect of closing a pipe of, suddenly, 28
its appearance, 198
temperature at which it scalds, 127
two ounces of coal evaporate a pint, 158
undulations or waves of, how made to destroy each other, 82
wheels, four forms of, 41
where found purest, 313
why in motion when boiling, 109
melts salt, 22
sugar, 23
Waters, flowing, 313
Watt, his improvements, 165
Wave, phenomena occasioned by the passage of a boat, 77
Waves of sea, cause of, 131
of water, effect of oil on, 60
how produced, 60
Wax becomes hard when cold, why, 143
soft before it melts, why, 143
Weather foretold by animals and insects, 229
popular opinions of, 227
cold, 270
Weaving, 429
Wedge, definition of, 39
uses of, in the arts, 40
Weeds, 453
Weight, 15
avoirdupois, definition of, 16
definition of, 15
false, method of detecting, 37
of aërolites, 228
of a man on the surface of the sun, 15
Troy, definition of, 16
Weights and measures, the French system of, 17
when adopted, 17
Wells, 519
Artesian, 520
Dr., on the theory of dew, 121
West Indies, region of hurricanes, 195
Wet clothes dry in the air, 146
Whales, seals, &c., how protected against cold, 104
Wheatstone invented the stereoscope, 256
Wheel, advantage of fly, 164
and axle, 38
centre of gravity of, 13
water, breast, 42
overshot, 42
turbine, 42
undershot, 42

Wheelbarrow, a lever of what kind, 35
Wheels, axles of, why greased, 97
of carriages, fore wheels why smaller than the hind wheels, 52
why arched or disc-shaped, 52
tires of, fitted hot, 136
Wheelwrights, why fit tires red hot, 136
Whirlpools, 198
Whirlwinds, 198
White, cause of, 248
light, 242
vitriol, 380
White lead, 382
Wick of candle not consumed, 341
Wild animals not fat, 354
Wind, action of, in sailing, 5
affects the shape of clouds, 200
always blows, 189
clouds affect it, 189
definition of, 60, 189
feels cold, why, 199
force of, how ascertained, 190
pipe, construction of, 80
temperature of, changes its direction, 189
velocity of, 190
why generally feels cool, 199
would blow regularly, when, 189
Winds, cause of, 188
constant, 190
do not always blow one way, why, 189
easterly, how prevent dew-falls, 115
why dry, 117
north, generally cold, 193
periodical, 192
south, generally warm, 193
trade, 190
variable, 193
where prevail, 193
westerly, favour the deposition of dew, 118
why moist, 118
which are dry, 194
are rainy, 194
Windows, why made to rattle by the passage of vehicles in the streets, 78
Wine, manufacture of, 396, 397
or beer turns sour, when, 391
sometimes red or yellow, 397
Wood, constituents of, 332
decay of, 328
dry, burns better than green, 130
why swells in water, 24
expands under the influence of heat differently from metal, 138
how made flexible by boiling, 184
light and porous makes the most snapping, 4
snapping of, during combustion, 4
unseasoned, decays, 402
why not melt with heat like metals, 143
preserved by paint, 106
some varieties float, and others sink, 22
warped by heat, 151
Wool, 424
fur and hair, why a protection against heat, 103, 104
has great attraction for colouring substances, 431
seen under a microscope, 424
Woollens and furs do not impart heat, 102.
why used for clothing in cold weather, 103
Woof, 429
Worcester, experiments of Marquis of, 164
Writing paper, 430

Yeast, 395
causes bread to rise, 328
Yellow light, how prevents germination of seeds, 266
rays most visible, 250
Yolk of an egg, 404

Zenith, 257
Zig-zag lightning, 276
Zinc, 287
sulphate of, 380
Zodiacal light, 226
Zoological geography, 538
definition of, 538
difference from zoology, 538
fauna, 539
definition, 539
dependent on vegetation, 539
temperate, 540
tropical, 540
arctic, 541


CASSELL'S
EDUCATIONAL